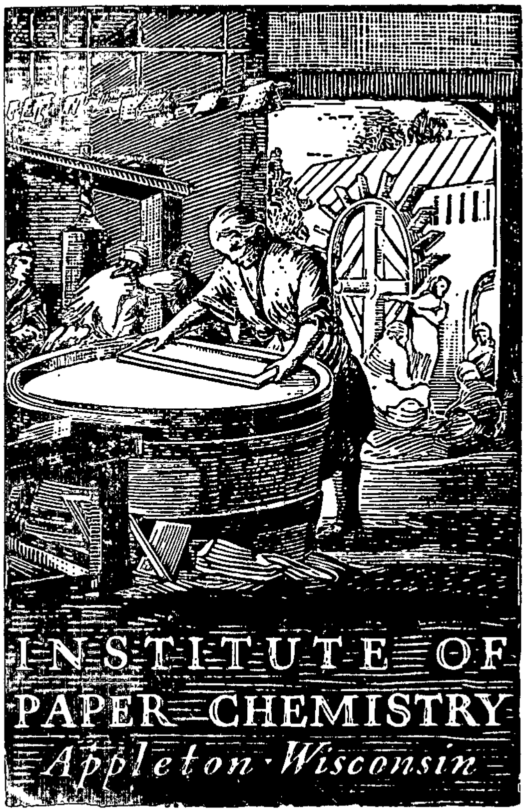

EFFECT OF CHEMICAL TREATMENTS ON OCC PROPERTIES

Project 2697-3

Report Two

A Progress Report

to

FOURDRINIER KRAFT BOARD GROUP

OF THE

AMERICAN PAPER INSTITUTE

May 19, 1980

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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SUMMARY

The overall objective of this program has been to develop ways of using increasing amounts of recycled fiber in linerboard without sacrificing board quality and productivity. One approach to improving the bonding potentials of recycled fiber is to utilize chemical treatments which will increase swelling, delignification and fibrillation of the fiber.

The effects of a number of treatment agents on composite old corrugated (OCC) have been studied. The treatments considered may be separated into two categories, namely:

1. Caustic soda (sodium hydroxide) at atmospheric pressure and 198°F
2. Elevated pressure and temperature treatments in the Asplund mill using green liquor, white liquor, caustic soda, sodium carbonate and hydrogen peroxide

The planned research involving these treatments has been completed and the results are summarized herein. In general the treatments studied produced only modest changes in most properties of repulped OCC. This held true for both the atmospheric pressure and Asplund mill treatments. However, parts of the work suggested that research on fiber/fines separation and disposal or long/short fiber fractionation may be desirable. A more detailed summary of the results is given below.

CAUSTIC SODA — ATMOSPHERIC PRESSURE

Treatment levels of 3 and 5% caustic soda based on o.d. fiber weight were employed. These treatments decreased freeness by about 50 cc at each beating interval. In general these atmospheric pressure treatments tended to produce only modest changes in most test properties.

ASPLUND MILL TREATMENT — CAUSTIC SODA AND GREEN LIQUOR

For these trials 3% treatment levels were employed and results were compared to both the untreated OCC and a control stock processed through the Asplund with no chemical added (Asplund control). After treatment, two collection and washing techniques were studied. In one case the stock was collected and washed in a Buchner funnel so as to prevent loss of fines. In the other case the stocks were screened and collected on a muslin covered flat box. This resulted in a loss of fines of about 12% in both the Asplund control and chemically treated stocks.

Case 1 — Fines Retained

1. The yields were about 90 and 96% for the caustic soda and green liquor treatments respectively. The somewhat lower yield obtained with caustic soda may be due in part to the more drastic Asplund conditions used in the caustic soda trials as well as chemical reactivity differences.

2. Both agents caused large reductions in freeness relative to the untreated OCC at the various beating intervals.

3. At a given density, the bursting strengths of the green liquor treated stocks were lower than either the Asplund

control or untreated OCC. For caustic soda, the bursting strength of the treated stock was about equal to that of the untreated OCC.

4. At a given freeness both agents tended to produce modest increases in bursting strength relative to Asplund control. However, the results after chemical treatment were either lower or about equal to those attained with the untreated OCC which was not processed through the Asplund. The caustic treatment appeared to be slightly more effective than green liquor.

5. These treatment agents tended to produce somewhat higher tearing strength at a given freeness than the untreated OCC. However, the edgewise compression strengths after treatment tended to be about equal to or lower than the untreated OCC at a given freeness.

Case 2 — <u>Fines Removed</u>

1. The removal of fines materially increased the freeness of the Asplund control and treated stocks relative to the untreated OCC. This would be expected because of the known effects of fines on drainage.

2. At a given density, the bursting strengths of the Asplund control were higher than those of untreated OCC. The treatments tended to lower bursting strength relative to the Asplund controls.

3. At a given freeness the Asplund controls and treated stocks exhibited considerably higher bursting strength and tensile strengths than the untreated OCC. However, somewhat lower edgewise compression strengths were generally attained after treatment as compared to the untreated OCC.

SODIUM CARBONATE AND OTHER AGENTS

Treatments with sodium carbonate in the Asplund tended to produce small improvements in burst and tensile and some decrease in edgewise compression strength. In general, the effect of an 8% sodium carbonate treatment appears to be about the same as obtained with 3% caustic soda. Hydrogen peroxide at the 2% application level did not have much effect on most properties.

CHARACTERIZATION OF FURNISHES

For reference purposes beater evaluations were carried out on the following stocks:

1. virgin kraft pulp
2. composite OCC
3. liner fraction of OCC
4. medium fraction of OCC

In general, the softwood liner fraction has good strength potentials in terms of burst and related properties as expected, whereas the hardwood fibers are low in burst and freeness. On the other hand, the hardwood medium fibers tend to have high edgewise compression strength. Because of the differences in fiber species and degree of delignification, the softwood and hardwood fractions will respond differently to mechanical and chemical treatment. Therefore, fractionation followed by separate treatment of either or both fractions may warrant further research.

INTRODUCTION

A research project to maximize recycled fiber use in linerboard is being carried out at the Institute in cooperation with the Fourdrinier Kraft Board Group of the American Paper Institute. Increased use of recycled fiber will assist the industry to reduce needs for new capital investment, keep pollution abatement costs down and conserve resources. The objective of the project is to develop methods for using increased amounts of recycled fiber without sacrificing board quality or productivity.

The first phase of the study involved a survey of the technical state of the art. The survey findings were summarized in Progress Report One (1).

One approach to improving the bonding potentials of recycled fibers is to utilize chemical treatments which will mildly increase delignification, swelling, or fibrillation of the fibers. A series of trials has been carried out to compare the effectiveness of various chemical treatments of OCC. The treatments considered may be divided into two catagories, namely:

1. Atmospheric pressure treatments using caustic soda
2. Elevated pressure and temperature treatments in the Asplund mill as follows:
    a. caustic soda
    b. sodium carbonate
    c. hydrogen peroxide
    d. "green" liquor
    e. "white" liquor

The results obtained are summarized in this report. In addition to the above, background information on the strength characteristics of repulped OCC and its liner and medium fractions is discussed.

The effects of repulping on the strength properties of the paper or board made from recycled fiber furnishes have been studied by a number of investigators. A review of the literature is contained in Report One.

Based on the review, there appears to be agreement that recycled fibers differ significantly from virgin fibers (and papers made therefrom) in many of their properties. When the recycling is carried out to maintain a given strength level — e.g., bursting strength — it has been found that it is necessary to refine to progressively lower freeness in each recycling. Thus, on successive recycling, the freeness and fiber length decrease because of "fines" generation and can reach impractical levels in terms of production rates and sheet performance. In contrast, at constant freeness the properties of the paper which are mainly dependent on fiber bonding and strength decrease markedly with the number of times the fiber is recycled. One of the primary differences between virgin and recycled fibers appears to be related to the fact that the recycled fibers do not swell as readily in water and, hence, do not bond as well. These differences in bonding potential can be overcome, at least in part, by additional refining, by the use of chemical swelling and bonding agents and by increased wet pressing. Thus, paperboards may be made in whole or in part from recycled fibers and exhibit satisfactory commercial quality. This is evidenced by the fact that many mills producing linerboard presently employ significant percentages of recycled fiber.

OCC is composed of two fibrous components — linerboard and corrugating medium — which can be separated in the wet by suitable screens into long and short fiber fractions. On the average these fractions are in the ratio of 2:1 long fiber:short fiber. These two fractions differ strikingly in terms of fiber composition. If the "cut" is made properly, the long fraction will contain mainly unbleached softwood fibers which have reasonably good strength potentials. In contrast, the short fraction will consist mainly of hardwood fibers and short wood cell components which have lower strength potentials — at least for some properties such as bursting strength.

It is to be expected that the two fractions will react differently to various mechanical or chemical treatments because of the differences in fiber species degree of delignification, etc. Therefore fractionation provides the opportunity to treat each fraction separately. However, both fractions must be used to make the process economically attractive. While the chemical treatments discussed in this report were carried out on the composite OCC, separate treatments of either or both fractions may be more effective.

A number of investigators have discussed ways to fractionate OCC or other fibers. A review of this literature is contained in Ref. 1. In general, it appears that fractionation can be accomplished commercially and may have advantages in some cases.

MATERIALS

VIRGIN PULP

For reference purposes supplies of both top and bottom kraft liner pulps were obtained from an FKBG member company. The bottom liner (primary) slush pulp was obtained after the Vertifiner before high density storage. The kappa number was about 90-95. The top liner (secondary) was obtained from the washer before high density storage. The kappa number was about 58-65.

The fiber analyses on these pulps are shown in Table I.

TABLE I

FIBER ANALYSIS RESULTS
ON VIRGIN PULP

	Bottom Liner Pulp	Top Liner Pulp
Fiber composition, %		
Softwood unbleached kraft	95.0	100-
Hardwood kraft	5.0	trace+
Bauer-McNett Fiber Classification (at 705 cc C.S. freeness)		
On 12 mesh, %	49.5	--
On 28 mesh, %	21.4	--
On 48 mesh, %	10.5	--
On 100 mesh, %	4.4	--
Through 100 mesh, %	14.2	--

To minimize deterioration during the life of the project, the pulps were dewatered and stored under freezing conditions. A limited study was carried out to check the effect of storage under freezing conditions using a northern kraft pulp. The results indicated that the physical properties of the stock previously stored under freezing conditions were about the same as on the "as received" stock. However, the frozen stocks did require somewhat longer beating times to reach the same freeness levels as the "as received" stock.

OCC SUPPLY

The "old corrugated" sample was obtained in the form of 200 lb test C-flute combined board sheets using selected linerboard and medium components. The selection of components was guided by the Recycled Fiber Subcommittee of FKBG. The fiber analyses of the selected components are shown on Table II.

TABLE II

FIBER ANALYSES OF OCC COMPONENTS

	Amount, %
NSSC Corrugating Medium	
Hardwood NSSC	72.6
Softwood unbleached kraft	21.0
Hardwood unbleached kraft	6.4
Single and Double-Face Liners	
Softwood unbleached kraft	95.0
Hardwood unbleached kraft	5.0
Bauer-McNett Fiber Classification	
On 35 mesh, %	62.2
On 65 mesh, %	17.0
On 100 mesh, %	3.7
On 150 mesh, %	2.1
Through 150 mesh, %	15.0

While the above corrugated sample is referred to as OCC in this report, it is recognized that it does not contain the residual contaminants present in post consumer old corrugated after cleaning. However, results obtained in other parts of the study indicated that its physical properties after repulping were comparable to commercial OCC pulps from a number of sources.

PROCEDURES

CHEMICAL TREATMENTS AT ATMOSPHERIC PRESSURE

Repulped OCC at 4% consistency was treated with NaOH using concentrations of 3 and 5% based on the weight of ovendry (o.d.) fiber. These concentrations were selected based on the work of Seifert and Long (2) who reported an increase in bursting strength of about 25% using 4% NaOH. The stocks were treated for two hours at 198°F at each concentration. After treatment the pulps were dewatered in a centrifuge and washed in a centrifuge to a pH of 9-10.

The yields for these treatments ranged between 94-96%. These yields were about the same as obtained by Seifert and Long.

Beating curves were obtained at each condition. TAPPI standard sheets were prepared at each beating interval and the sheets were plate dried.

ELEVATED TEMPERATURE AND PRESSURE TREATMENTS

Part 1 — Caustic and Green Liquor Using Different Washing Techniques

A series of treatments was carried out in the Asplund defibrator to simulate the effects of chemical treatments in asphalt dispersion systems. One series of trials was carried out using caustic soda and green liquor. The conditions employed are shown in Table III. The processing was carried out using 135 g of o.d. fiber per charge to the Asplund with the selected amount of chemical. The composition of the synthetic green liquor was as follows:

Sodium carbonate: 77.1 g/500 mL
Sodium sulfide: 15.7 g/500 mL

TABLE III

EXPERIMENTAL TREATMENTS USING CAUSTIC AND GREEN LIQUOR
WITH DIFFERENT WASHING TECHNIQUES

		Asplund Condition			
Agent[a]	Concentration, % o.d. fiber	Dwell Time, min	Steam Pr., psi	Post Treatment Washing	Yield, %
Untreated	0	5.0	100	Screen/flat box	84.6
NaOH	3	5.0	100	Screen/flat box	77.8
Untreated	0	2.5	50	Screen/flat box	83.3
Green liquor	3	2.5	50	Screen/flat box	81.8
Untreated	0	5.0	100	Funnel[b]	96.2
NaOH	3	5.0	100	Funnel[b]	90.1
Untreated	0	2.5	50	Funnel[b]	96.1
Green liquor	3	2.5	50	Funnel[b]	95.6

[a]Treatment consistency was 25-30%. Duplicate treatments and beater runs were made at each condition.
[b]Treated stock was washed in a sintered glass funnel to prevent "fines" loss.

Shorter dwell time and lower steam pressure were employed for the green liquor as compared to the caustic soda trials. The green liquor treatment conditions were recommended by the Reclaimed Fiber Subcommittee.

The chemically treated stock was placed in the prechamber of the Asplund and heated for the prescribed period. The pulp was then blown into the defibrator chamber and fiberized for about 75 seconds. Tap water was then blown into the defibrator from the prechamber using 150 psi steam and the pulp was blown into a cyclone separator using 100 psi steam. Tap water was again introduced into the defibrator chamber, the defibrator motor was started, and the water was blown into the cyclone. The several charges required for each treatment were then mixed.

After treatment the stocks were washed in two ways. In one case, to prevent losses of "fines", the pulp was dewatered and washed using a sintered glass funnel. This resulted in a loss of solubles of about 5-10% for the chemical treatments (see Table III). In the other case the pulps were washed on a Valley screen and muslin covered wash box. This resulted in lower yields since both solubles and "fines" were lost. Based on the differences in yields in Table III it appears that the fines loss amounted to about 12-14% for the two types of chemical treatment when the pulp was washed on the flat box.

Duplicate treatment trials were carried out and separate beater runs were made for each trial. Standard weight sheets were made at each beating interval and plate dried. The test results for the duplicate trials were averaged.

<u>Part 2 — Sodium Carbonate and Other Agents — Screen/Flat Box Washed</u>

A series of Asplund trials were made with sodium carbonate and other agents as shown in Table IV. The same procedures were employed as in Part 1 except that only single trials were made for each treatment condition and all treated stocks were washed on the screen and flat box. Thus the yields are low because of loss of "fines."

TEST PROCEDURES

The handsheets were evaluated for the following properties using TAPPI procedures where possible:

1. Basis weight: (10 sheets)
2. Caliper: 10 tests

3. Density: by calculation

4. Tensile, stretch, tensile stiffness (Et) and tensile energy absorption (TEA): 10 tests

5. Modified ring compression: 10 tests

6. Elmendorf tear: 4 tests

7. Concora: 6 tests*

8. Z direction tensile (American Can type): 5 tests*

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*At selected conditions in 26 lb/1000 ft^2.

TABLE IV

ASPLUND TREATMENT CONDITIONS FOR WHITE LIQUOR AND OTHER AGENTS

Agent	Concentrate, % o.d. fiber	Asplund Condition: Dwell Time, min	Asplund Condition: Steam Pressure, psi
Untreated	0	2.5	50
White liquor	3	2.5	50
White liquor	5	2.5	50
Green liquor	3	2.5	50
Green liquor	5	2.5	50
Untreated	0	5.0	100
Na_2CO_3	8	5.0	100
	13.2	5.0	100
NaOH	3	5.0	100
	5	5.0	100
H_2O_2	2	5.0	100

Note: Treatment consistency was 25-30%. A single beater run was made for each treatment. The treated stock was screened and flat box washed.

CHARACTERISTICS OF VIRGIN, OCC AND OCC FRACTIONS

To provide baseline data on the strength potentials of the base materials obtained for the study, beater runs were carried out as follows:

1. Virgin primary kraft pulp
2. Composite OCC
3. Liner fraction of OCC
4. Medium fraction of OCC

The liner and medium fractions were obtained by wetting the OCC combined board and hand separating the liners from the medium. For this phase of the study the handsheets were prepared to a basis weight of 42 lb/1000 ft^2. The sheets were wet pressed at 90 psi and drum dried.

DISCUSSION OF RESULTS

CAUSTIC SODA TREATMENTS — ATMOSPHERIC PRESSURE

Repulped OCC at 4% consistency was treated with NaOH using concentrations of 3 and 5%. (The concentrations were selected based on the work of Seifert and Long (2) who reported that an increase of about 25% in bursting strength resulted from using 4% NaOH.) The stocks were treated for two hours at 198°F at each concentration. Beating curves were obtained at each concentration as well as on the untreated control.

The yields for these caustic treatments ranged between about 94-96% consisting of solubles. These yields are about the same as obtained by Seifert and Long (2).

The results obtained using the 3 and 5% caustic soda treatments at 198°F are summarized in Table V and compared at constant density and freeness in Table VI. Figure 1 shows that the caustic treatments decreased the freeness by about 25-50 cc at each beating interval which is probably due to swelling of the fibers by the caustic. The reductions in freeness were about the same for the two concentration levels. Figure 2 shows that the caustic treatments generally increased the burst and tensile factors at each beating interval. The percentage improvements in these properties tended to decrease as beating progressed.

Past work on ozonation (3) indicated that a 35% improvement in burst could be achieved with 2.3% O_3 consumption on unrefined OCC. The results in Fig. 2 suggest that caustic treatments near 7-8% might be required to achieve a 35% burst improvement. On the other hand, the tensile improvement of 24.4% with

TABLE V

EFFECT OF CAUSTIC TREATMENTS AT ATMOSPHERIC PRESSURE
(198° F)

Treatment, % NaOH	Temperature, °F	C.S. Freeness, mL	Basis Weight, lb/M ft^2	Caliper, mil	Apparent Density		Burst Factor		Tensile Factor	
					lb/mil	Diff, %	psi/lb	Diff, %	lb/inch/lb	Diff., %
0 Minute Beating Time										
0	--	652	13.6	5.8	2.34	--	1.27	--	0.90	--
3	198	615	13.6	5.3	2.56	+ 9.4	1.49	+17.3	1.03	+14.4
5	198	625	13.5	5.1	2.64	+12.8	1.62	+27.6	1.12	+24.4
5 Minute Beating Time										
0	--	592	13.8	5.5	2.52	--	1.68	--	1.15	--
3	198	555	13.6	5.0	2.74	+ 8.7	1.96	+16.7	1.26	+ 9.6
5	198	540	13.9	5.1	2.75	+ 9.1	2.02	+20.2	1.30	+13.0
10 Minute Beating Time										
0	--	528	13.6	5.2	2.62	--	2.01	--	1.31	--
3	198	490	13.7	4.8	2.84	+ 8.4	2.21	+10.0	1.42	+ 8.4
5	198	480	13.6	4.7	2.91	+11.1	2.34	+16.4	1.52	+16.0
20 Minute Beating Time										
0	--	372	13.8	5.0	2.80	--	2.57	--	1.52	--
3	198	315	13.4	4.5	2.93	+ 4.6	2.60	+ 1.2	1.73	+13.8
5	198	330	13.7	4.5	3.05	+ 8.9	2.57	0.0	1.71	+12.5
30 Minute Beating Time										
0	--	218	13.2	4.6	2.82	--	2.88	--	1.72	--
3	198	195	13.4	4.4	3.04	+ 7.8	2.92	+ 1.4	1.81	+ 5.2
5	198	190	13.5	4.3	3.12	+10.6	3.12	+ 8.3	1.86	+ 8.1

Note: Differences based on control at each interval. All factors were obtained by dividing the test result by the basis weight in lb/M ft^2.

TABLE V (continued)

EFFECT OF CAUSTIC TREATMENTS AT ATMOSPHERIC PRESSURE

% NaOH	Temperature, °F	Tear Factor, g/lb	Diff., %	Modified Ring Factor lb/inch/lb	Modified Ring Factor Diff., %	Et Factor lb/inch/lb	Et Factor Diff., %	TEA, ft-lb/ft^2	Diff., %	Stretch, %
0 Minute Beating Time										
0	--	6.44	--	0.288	--	124.8	--	1.9	--	1.82
3	198	6.43	-0.2	-.334	+16.0	126.8	+1.6	2.4	+26.3	2.03
5	198	6.45	+0.2	0.281	- 2.4	135.5	+8.6	2.9	+52.6	2.25
5 Minute Beating Time										
0	--	6.04	--	0.322	--	144.7	--	2.8	--	2.09
3	198	6.42	+6.3	0.337	+ 4.6	143.5	-0.8	2.9	+ 3.6	2.08
5	198	6.17	+2.2	0.301	- 6.5	143.2	-1.0	3.3	+17.8	2.24
10 Minute Beating Time										
0	--	5.73	--	0.354	--	151.8	--	3.4	--	2.20
3	198	6.03	+5.2	0.340	- 4.0	152.5	+0.5	3.6	+ 5.9	2.28
5	198	5.51	-3.8	0.353	- 0.3	160.9	+6.0	3.9	+14.7	2.32
20 Minute Beating Time										
0	--	5.39	--	0.361	--	165.6	--	4.4	--	2.49
3	198	5.03	-6.7	0.352	- 2.5	171.7	+3.7	4.9	+11.4	2.59
5	198	5.33	-1.1	0.375	+ 3.9	174.0	+5.1	4.5	+ 2.3	2.36
30 Minute Beating Time										
0	--	4.99	--	0.364	--	179.4	--	4.8	--	2.56
3	198	5.11	+2.4	0.355	- 2.5	178.9	-0.3	5.1	+ 6.2	2.56
5	198	4.89	-2.0	0.374	+ 2.7	185.6	+3.5	5.5	+14.6	2.67

TABLE VI

EFFECT OF ATMOSPHERIC PRESSURE TREATMENTS AT CONSTANT FREENESS AND DENSITY

Treatment, % NaOH	Burst Factor	Diff., %	Tensile Factor	Diff., %	Modified Ring Factor	Diff., %	Tear Factor	Diff., %	Density	Diff., %
600 cc Freeness										
0	1.62	--	1.11	--	0.318	--	6.10	--	2.49	--
3	1.62	0.0	1.11	0.0	0.335	+5.3	6.43	+5.4	2.63	+5.6
5	1.80	+11.1	1.23	+10.8	0.297	-6.6	6.30	+3.2	2.70	+8.4
500 cc Freeness										
0	2.11	--	1.34	--	0.35	--	5.70	--	2.65	--
3	2.15	+1.9	1.42	+6.0	0.341	-3.1	6.09	+6.8	2.82	+6.4
5	2.31	+7.5	1.51	+12.7	0.344	-2.2	5.74	+1.2	2.88	+8.7
300 cc Freeness										
0	2.73	--	1.59	--	0.367	--	5.16	--	2.82	--
3	2.64	-3.4	1.70	+6.9	0.353	-3.8	5.16	0.0	3.00	+6.4
5	2.78	+1.8	1.78	+11.9	0.372	+2.8	5.20	+0.8	3.05	+8.2
Density = 2.70 lb/1000 ft^2-mil (0.51 g/cc)										
0	2.28	--	1.40	--	0.358	--	5.56	+	--	--
3	1.80	-21.1	1.26	-10.0	0.338	-5.6	6.40	+15.1	--	--
5	1.80	-21.1	1.26	-10.0	0.296	-17.3	6.29	+13.1	--	--

Note: Differences based on control at each freeness. All factors were obtained by dividing the test result, usually in English units, by the basis weight in lb/1000 ft^2.

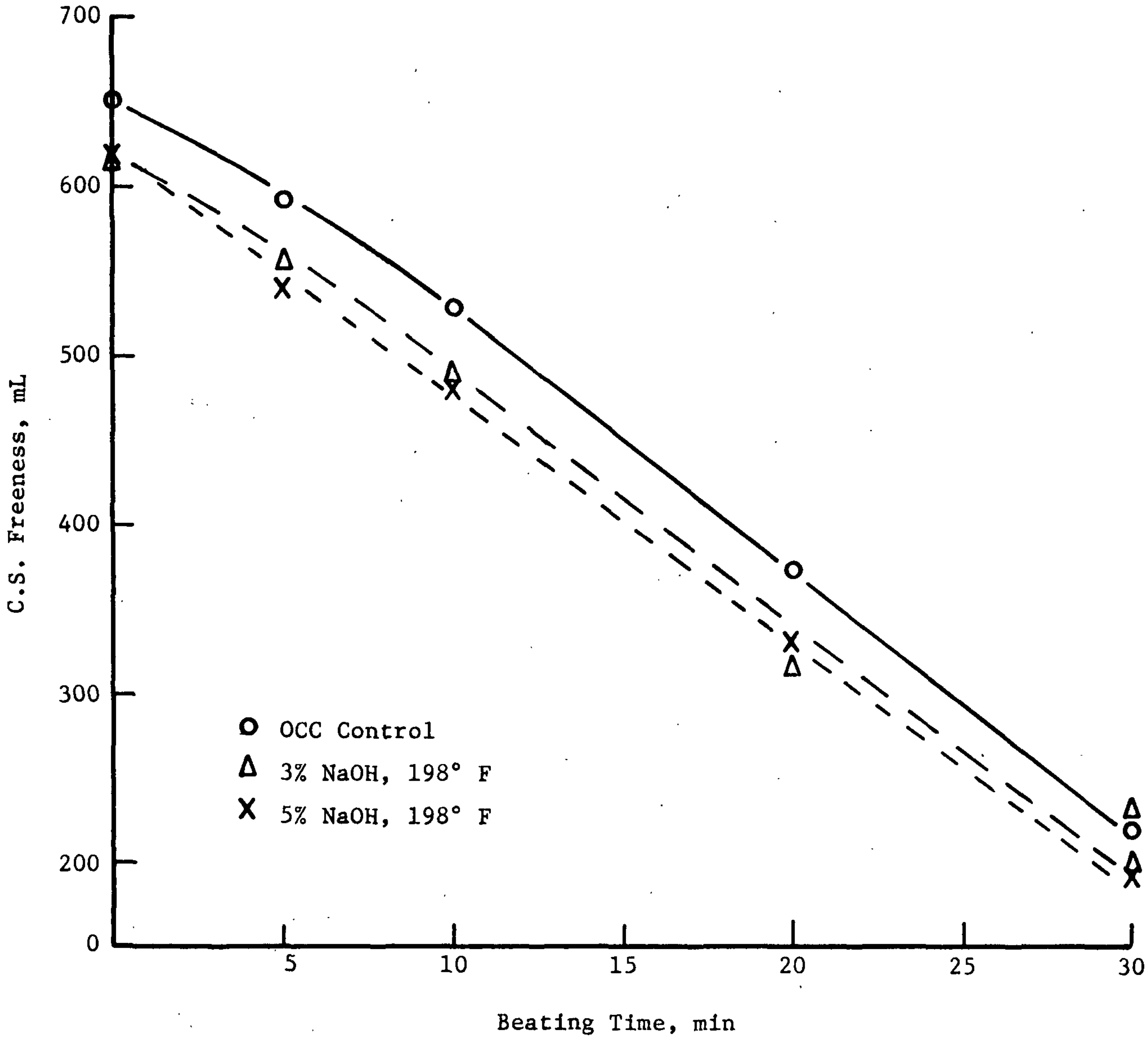

Figure 1. Effect of Atmospheric Pressure Caustic Treatments on Freeness

5% caustic at 198°F was approximately the same as that obtained at the 2.3% O_3 consumption level (27%) on unrefined stock (3).

The densities of the caustic treated stocks were higher than the untreated stock over the entire freeness range as shown in Fig. 3. Thus the caustic treatments

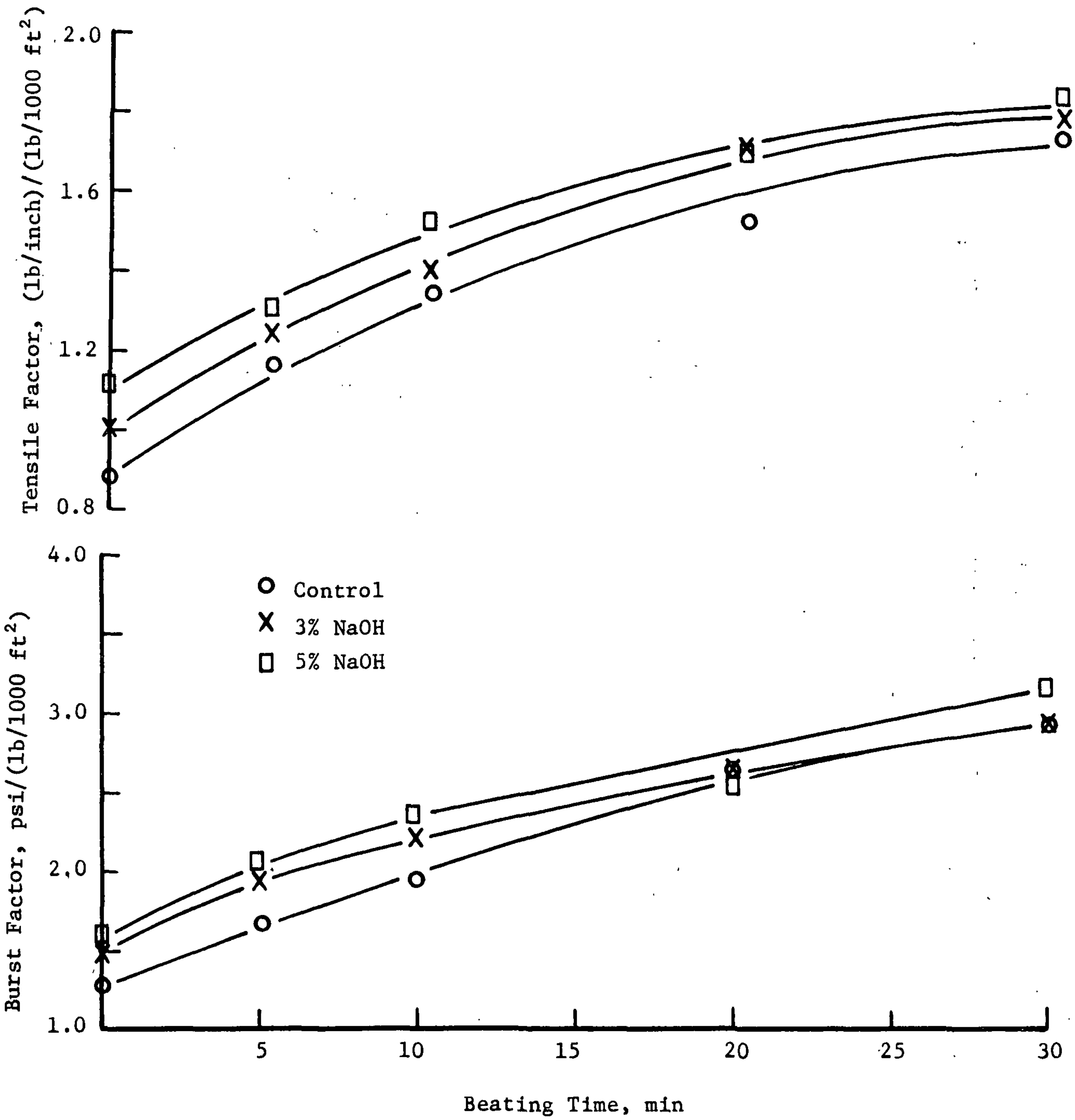

Figure 2. Effect of Atmospheric Pressure Caustic Treatments on Burst and Tensile Strength

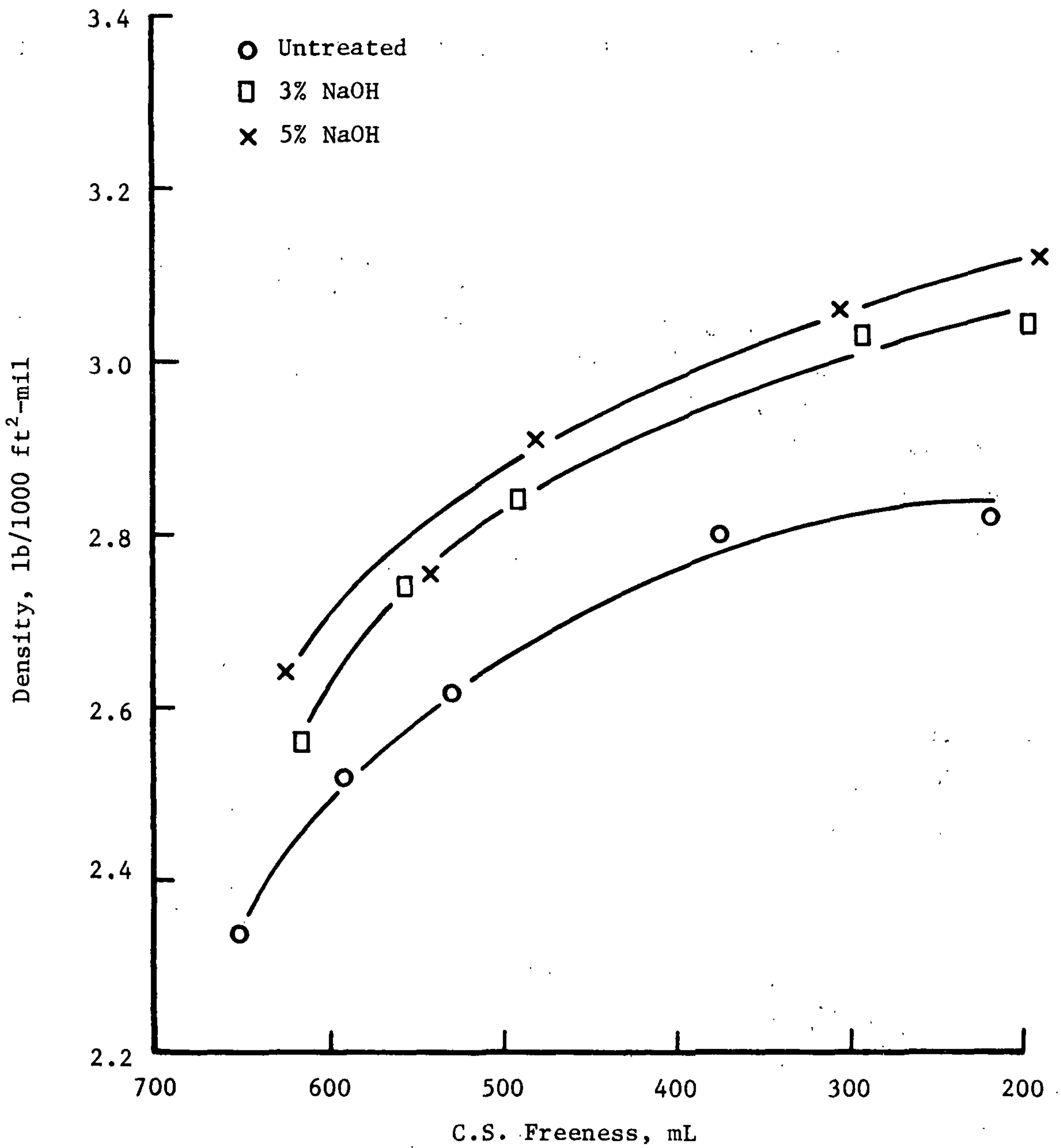

Figure 3. Effect of Caustic Soda Treatments at Atmospheric Pressure on Sheet Density

induced some swelling of the fibers which increased bonding and sheet density and lowered freeness.

At constant density the burst and tensile results for the caustic soda treatments were significantly lower than the corresponding results for the untreated control (Fig. 4 and 5). The 3 and 5% treatment results follow essentially the same

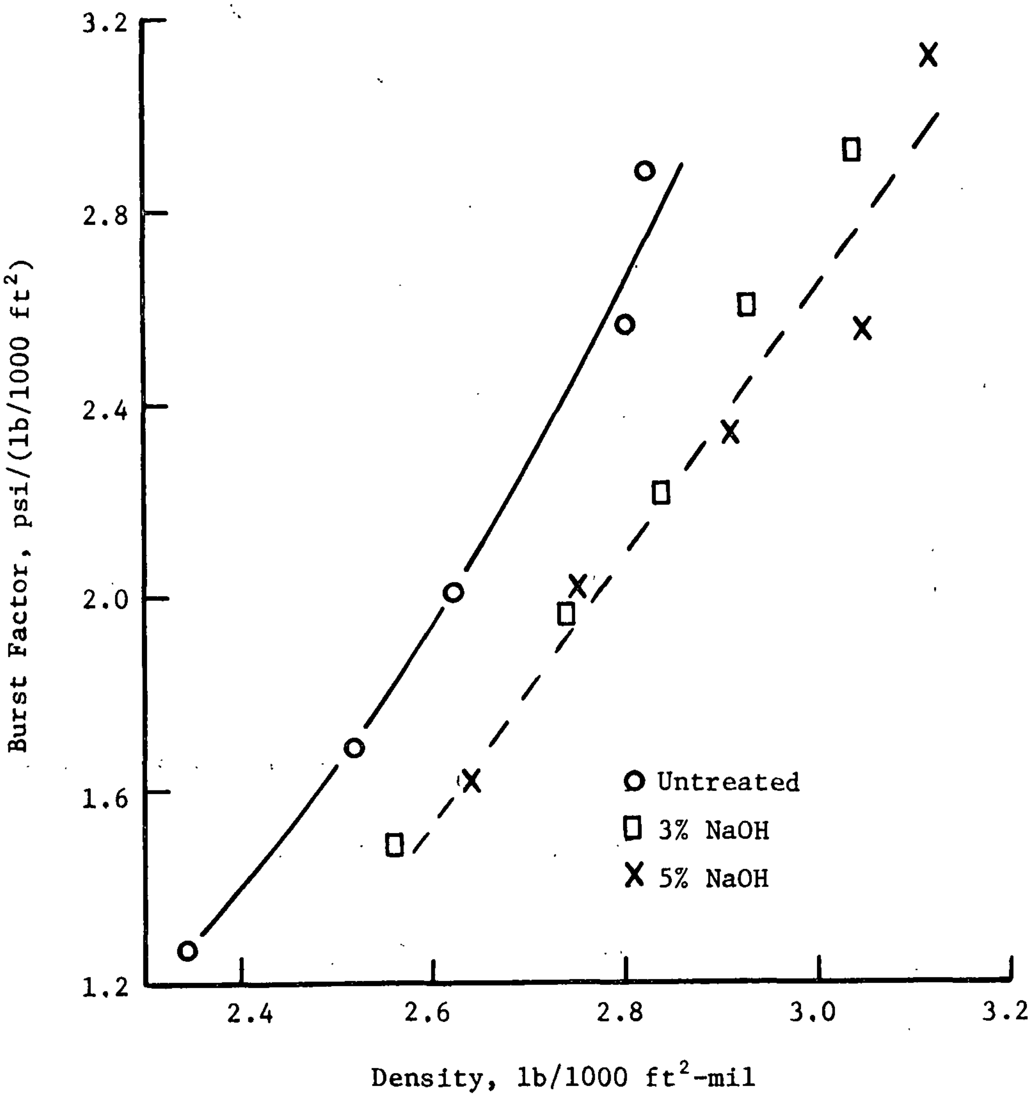

Figure 4. Burst vs. Density for Caustic Treatments at Atmospheric Pressure

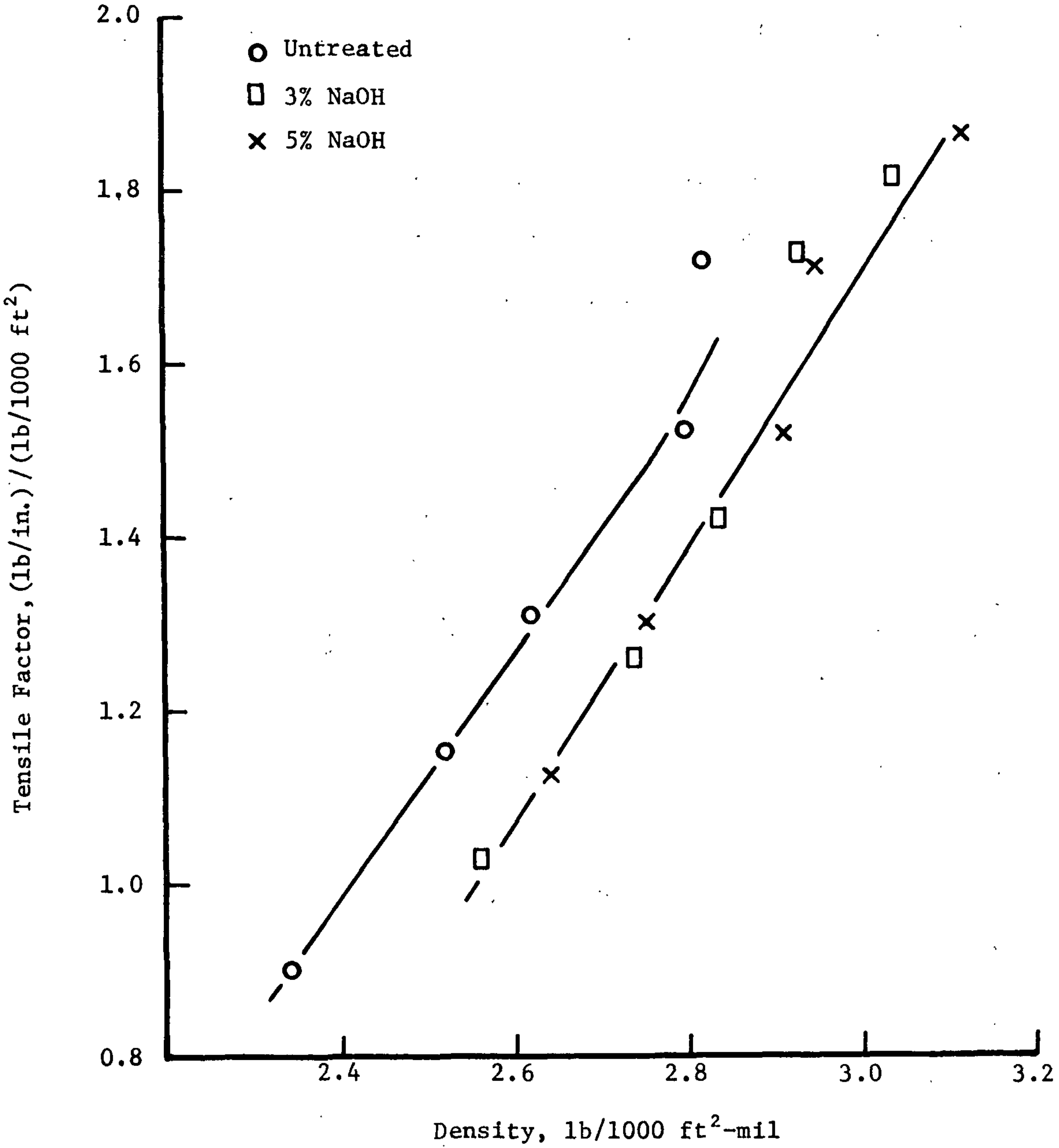

Figure 5. Effect of Caustic Soda Treatments at Atmospheric Pressure on Tensile vs. Density Relationships

relationship in each figure. Thus the effect of increasing the caustic concentration from 3 to 5% is to increase the density and hence burst and tensile for the same amount of beating.

When the burst factors are plotted against freeness, the results show that the 3% caustic treated samples exhibit about the same test levels as the untreated stock as shown in Fig. 6 and Table VI. At 500 and 600 mL freeness the 5% caustic soda treated stocks exhibited increases ranging from about 9-11% (Table VI). Thus relatively modest increases in burst strength were achieved with these caustic treatment conditions at constant freeness.

The tensile results in Fig. 7 show that the caustic treatments tended to slightly increase the tensile strength over most of the freeness range. For the 5% caustic soda treatment the percentage improvements were in the 11 to 13% range at the 600 and 500 mL freeness levels (Table VI). Thus the burst and tensile results show about the same degree of change at constant freeness.

The effects of the caustic treatment on modified ring compression strength in Fig. 8 are somewhat erratic which may be due, in part, to the difficulties of carrying out compression tests on thin sheets. With this reservation, at a given density the results indicate that these caustic treatments lowered compression strength. At constant freeness (Table VI) small positive and negative changes in compression strength were obtained. When the burst and compression results are compared in Fig. 9 the caustic treated sheets tend to give slightly lower edgewise compression strength at a given burst level.

The tensile vs. tear relationships are shown in Fig. 10. The results indicate that at a given tensile strength the caustic treated sheets generally exhibited slightly higher tear.

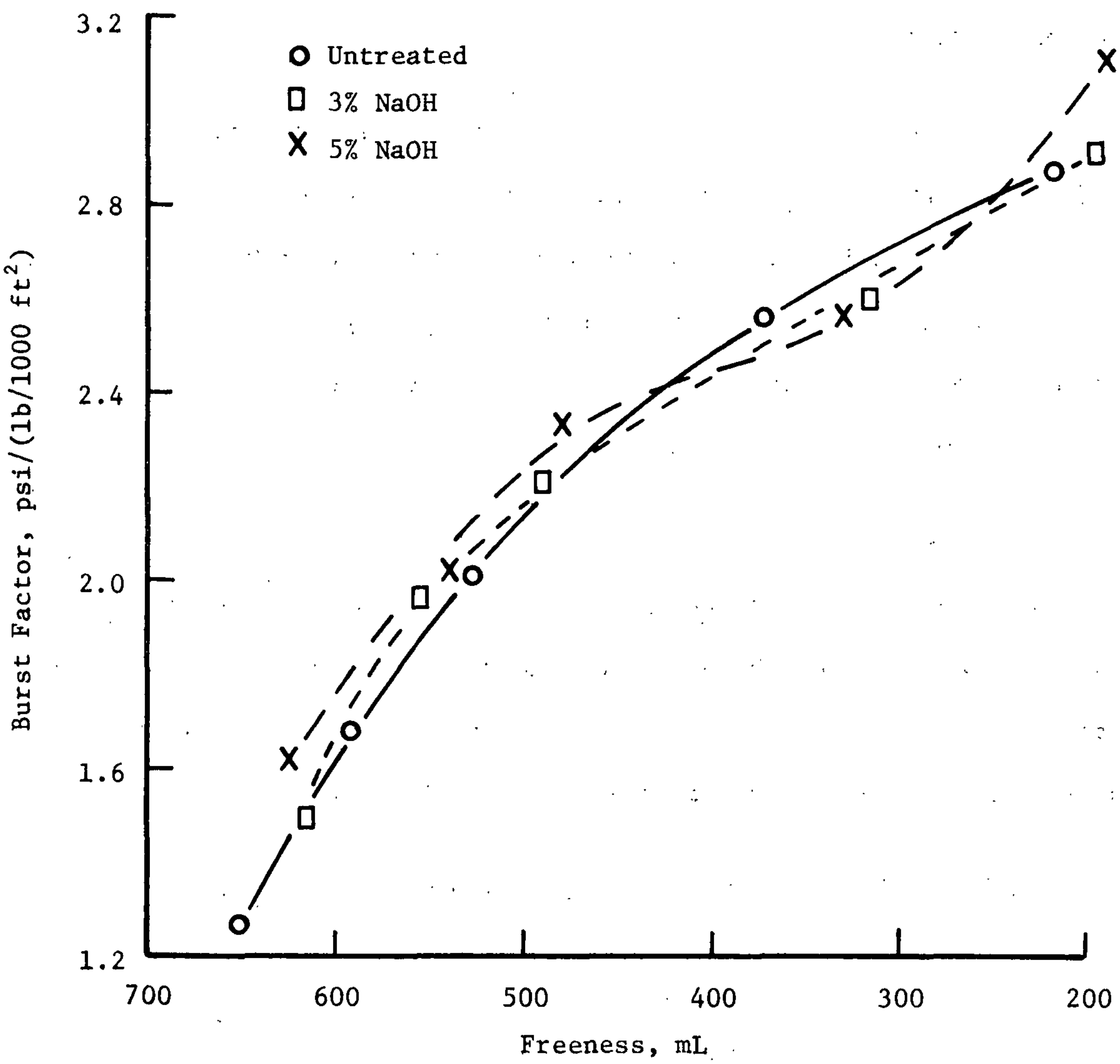

Figure 6. Effect of Caustic Treatments at Atmospheric Pressure on Burst vs. Freeness Relationships

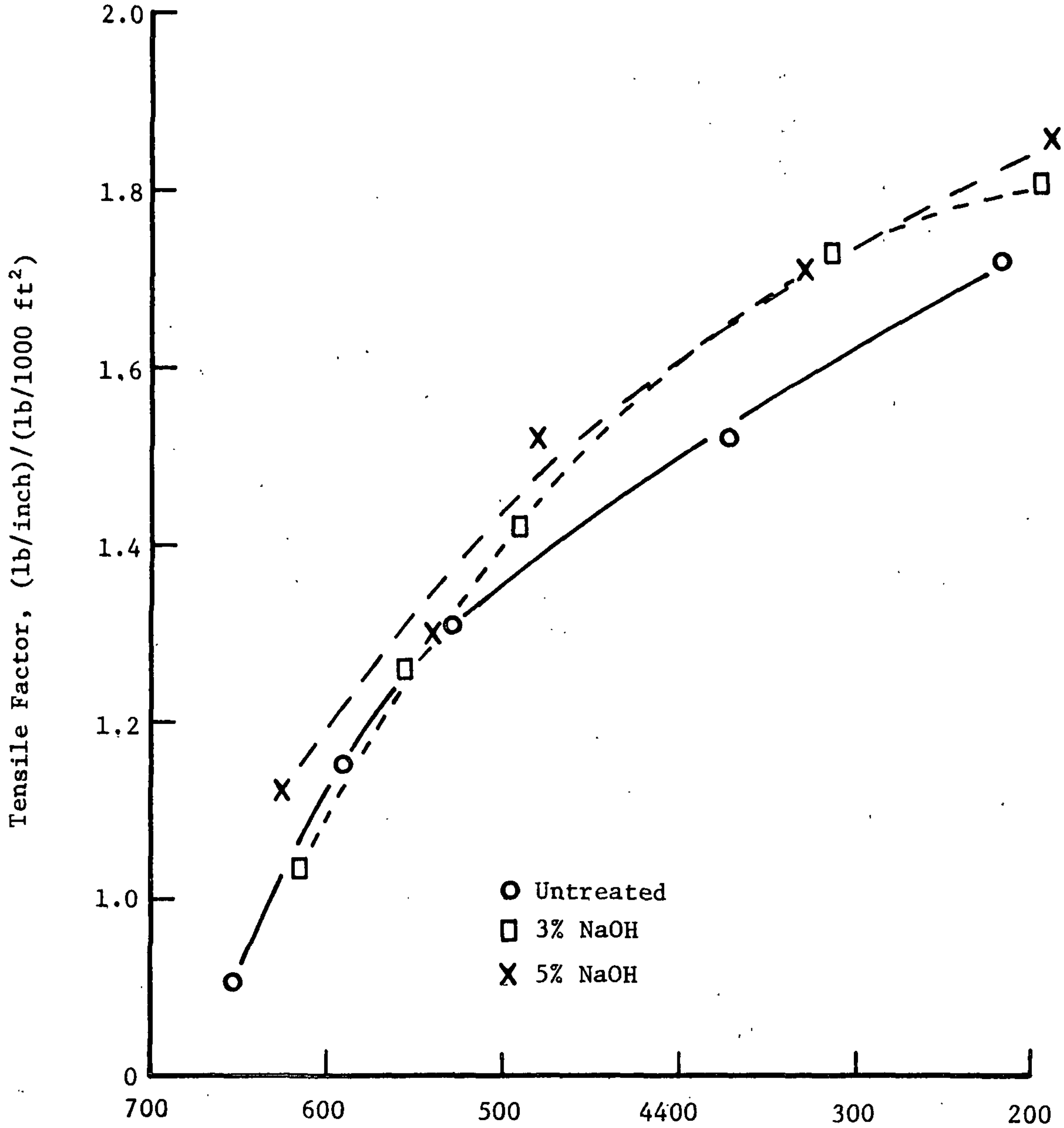

Figure 7. Effect of Caustic Treatments at Atmospheric Pressure on Tensile vs. Freeness Relationships

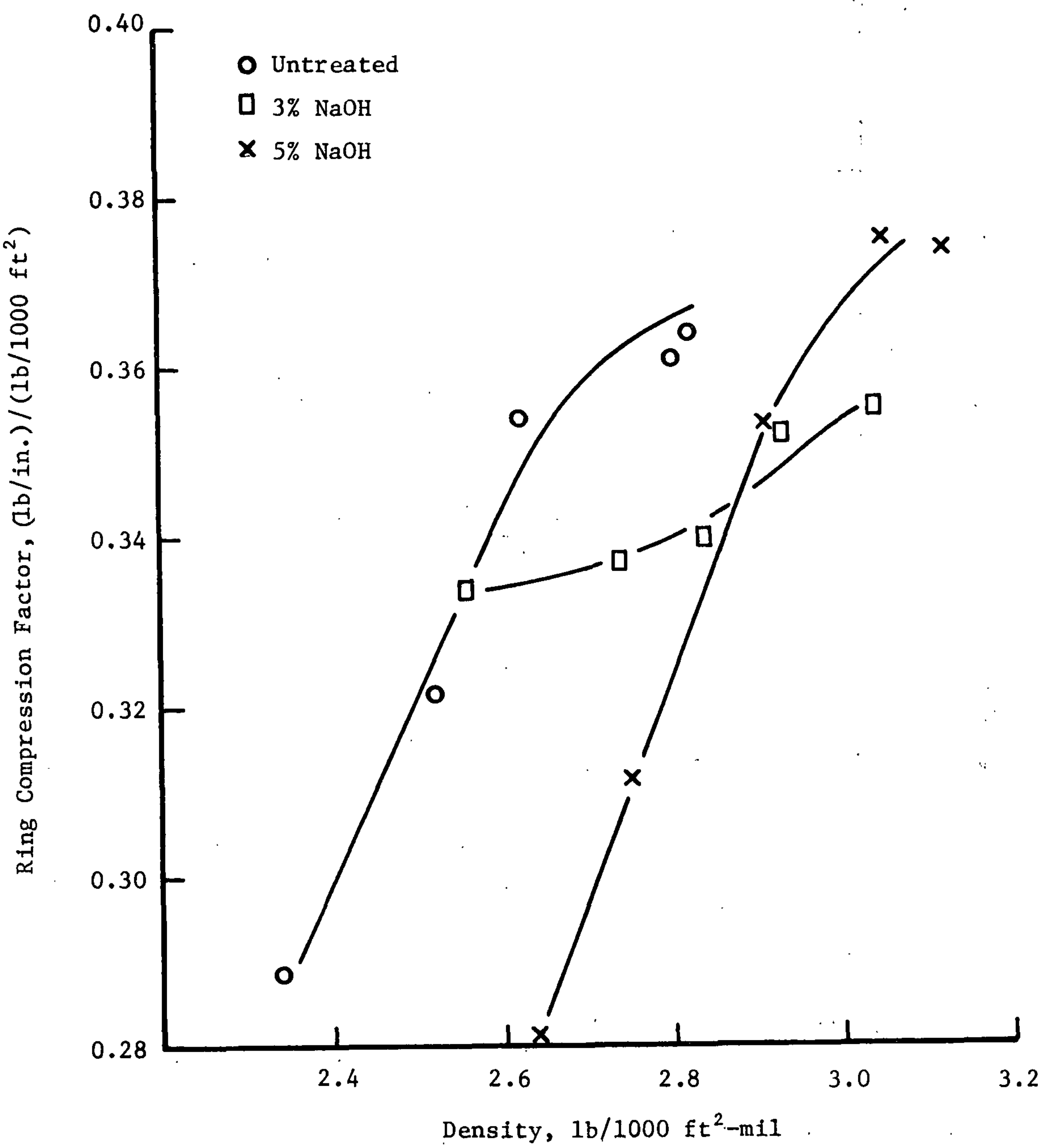

Figure 8. Effect of Atmospheric Caustic Soda Treatments on Edgewise Compression Strength

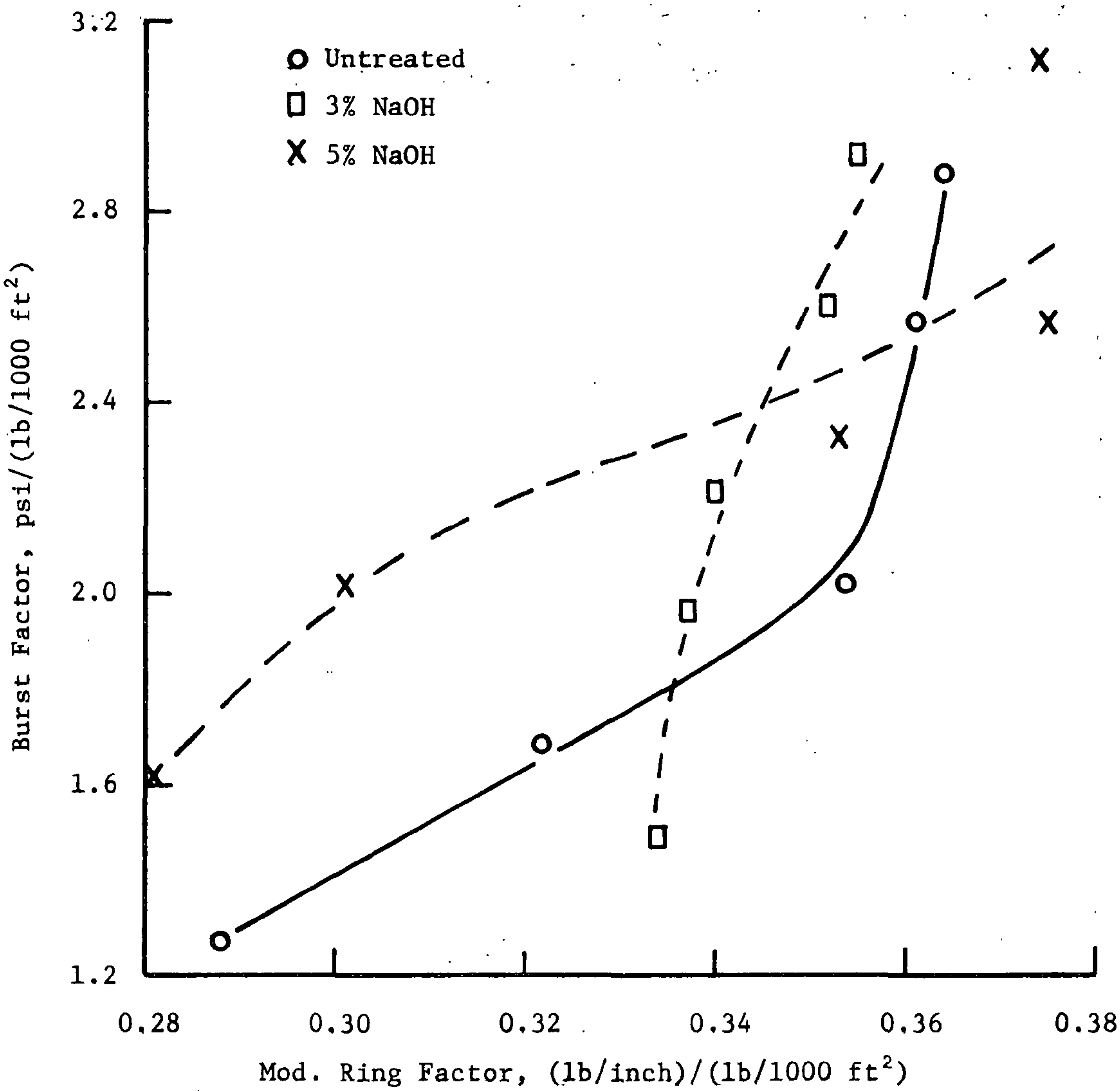

Figure 9. Effect of Atmospheric Pressure Caustic Soda Treatments on Burst vs. Compression Relationships

Briefly summarizing, these atmospheric pressure caustic treatments generally effected rather small changes in most test properties. It appears that higher concentrations or more drastic conditions would be required to significantly improve strength.

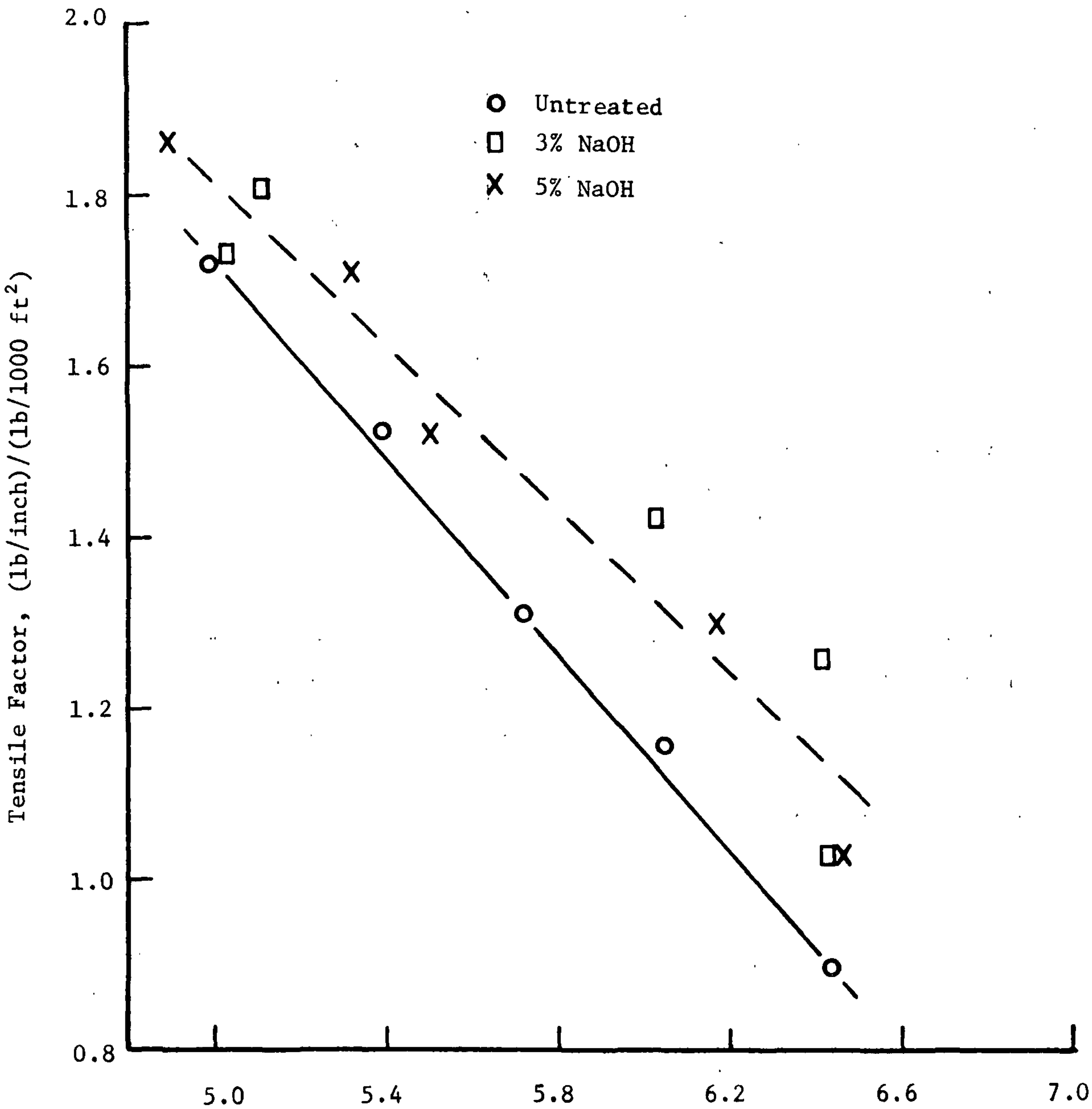

Figure 10. Effect of Atmospheric Pressure Caustic Treatments on Tensile vs. Tear Relationships

ELEVATED TEMPERATURE AND PRESSURE TREATMENTS

Part 1 — Green Liquor Caustic and Treatments

Treatments using caustic and green liquor were carried out in the Asplund defibrator to simulate the effect of chemical treatments in A/D systems. The following conditions were employed:

Caustic soda (NaOH): 3% on o.d. fiber, 5 min dwell time using 100 psi steam

Green liquor: 3% on o.d. fiber, 2.5 min dwell time using 50 psi steam

The lower time and steam pressure in the green liquor trials were suggested by members of the Reclaimed Fiber Subcommittee. Asplund control runs were also carried out at each Asplund condition.

After treatment in the Asplund, the stocks were washed in two ways as follows:

1. On a Valley screen and wash box which resulted in a loss of fines
2. On a sintered glass funnel to prevent fines losses

Table VII and Fig. 11 show that Asplund control yields after funnel washing were about 96+%. After treatment and collection in the funnel the yields were 90.1 and 95.6% for the caustic soda and green liquor treatments respectively. These yield losses may be attributed to loss of soluble matter. The somewhat lower yield obtained with caustic soda may be due in part to the more drastic time-temperature Asplund conditions used in the caustic trials as well as chemical reactivity differences.

After screen washing the Asplund control yields were about 83-85% and after chemical treatment the yields decreased to 78-82%. The change in yield due to

TABLE VII

YIELD AND FIBER CLASSIFICATIONS RESULTS

	Caustic Soda Trials		Green Liquor Trials	
	Flat Screen Washed	Funnel Washed	Flat Screen Washed	Funnel Washed
Yield, %				
Asplund Control	84.6	96.2	83.3	96.1
3% treatment	77.8	90.1	81.8	95.6
Fiber Classification, % — Asplund Controls				
On 35-mesh	70.6	62.8	72.3	61.3
On 65-mesh	19.6	16.4	13.4	17.7
On 100-mesh	6.0	5.6	10.3	5.0
On 150-mesh	2.0	2.4	2.2	1.6
Through 150-mesh	1.8	12.8	1.8	14.4
Fiber Classification, % — 3% Treatments				
On 35-mesh	69.9	64.4	72.4	61.6
On 65-mesh	17.9	15.6	18.6	17.0
On 100-mesh	5.5	4.4	5.4	4.4
On 150-mesh	2.2	2.4	1.8	2.6
Through 150-mesh	4.5	13.2	1.8	14.4

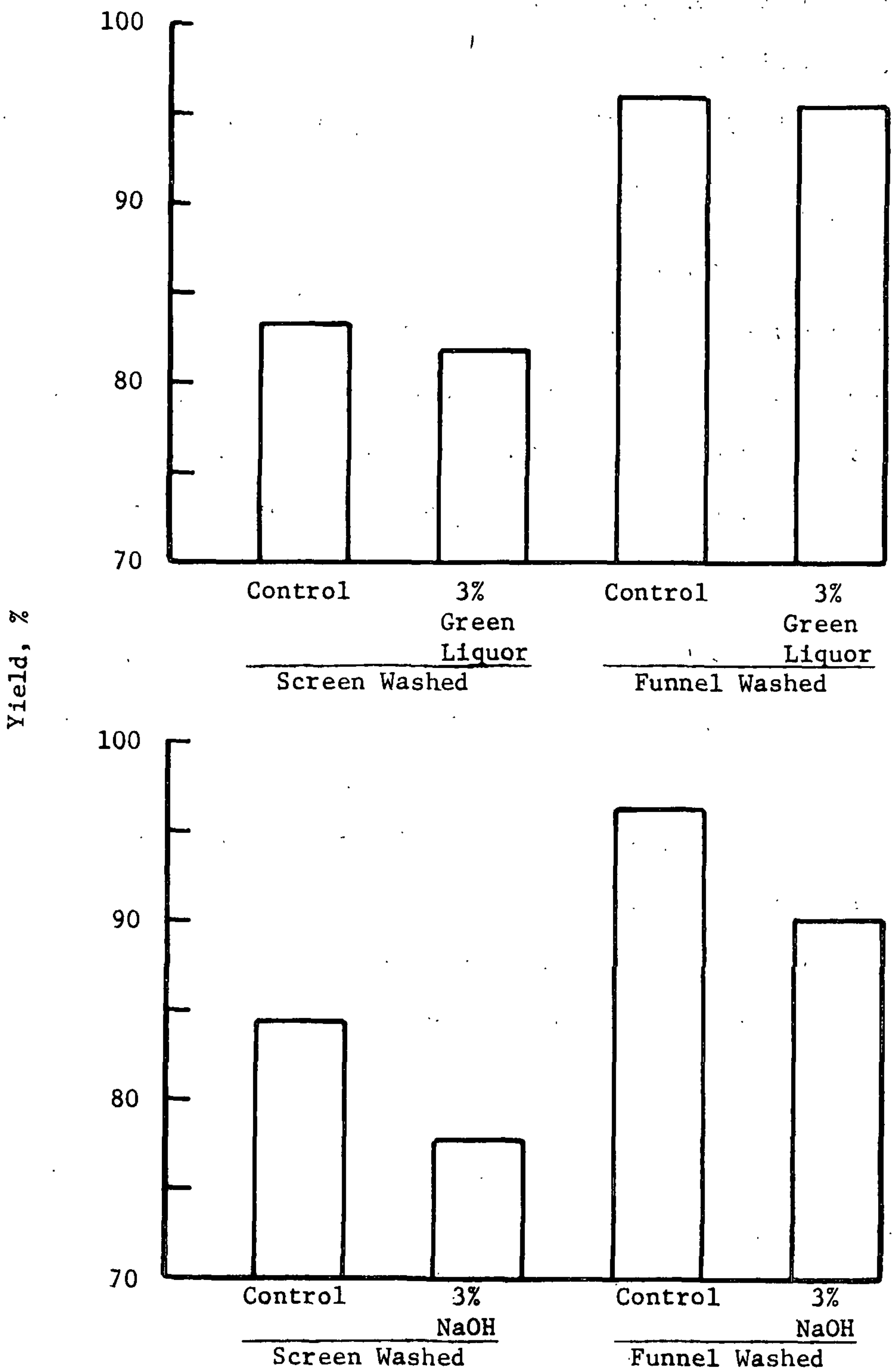

Figure 11. Effect of Treatment and Washing Conditions on Yield

washing technique was due to a loss in fines in the screen/wash box as indicated by the fiber classification results (Fig. 12). In the fiber classifications the funnel washed samples contained about 12-14% of material passing through 150 mesh, however after screen washing the through 150 fraction decreased to about 2-4%.

Green Liquor Beater Evaluation Results

The beater evaluation results on the green liquor treatments are tabulated in Table VIII. Various test properties are compared at 600, 500 and 350 mL C.S. freeness in Tables IX and X. In Table IX the differences in properties due to Asplund treatment are referenced to the properties of untreated OCC. In Table X the effects of the green liquor treatment are referenced to the untreated Asplund controls.

Figure 13 shows that the funnel washed Asplund control, where fines were retained, exhibited much lower C.S. freeness values at each beating interval than the untreated OCC which was merely defibered and beaten. After treatment with green liquor the funnel washed stock at about 95-96% yield exhibited freeness values which were about 50-100 mL lower than its Asplund control and about 130-150 mL lower than the untreated OCC. Thus, when the fines were retained the green liquor treatments in the Asplund resulted in major freeness reductions at each beating interval.

In contrast, Fig. 13 shows that screen/wash box washed stocks exhibited C.S. freeness values which were about 100-130 mL higher than the untreated defibered OCC. The increase in freeness is due to the loss of fines. The green liquor treated stock after screen washing exhibited slightly lower freenesses than its

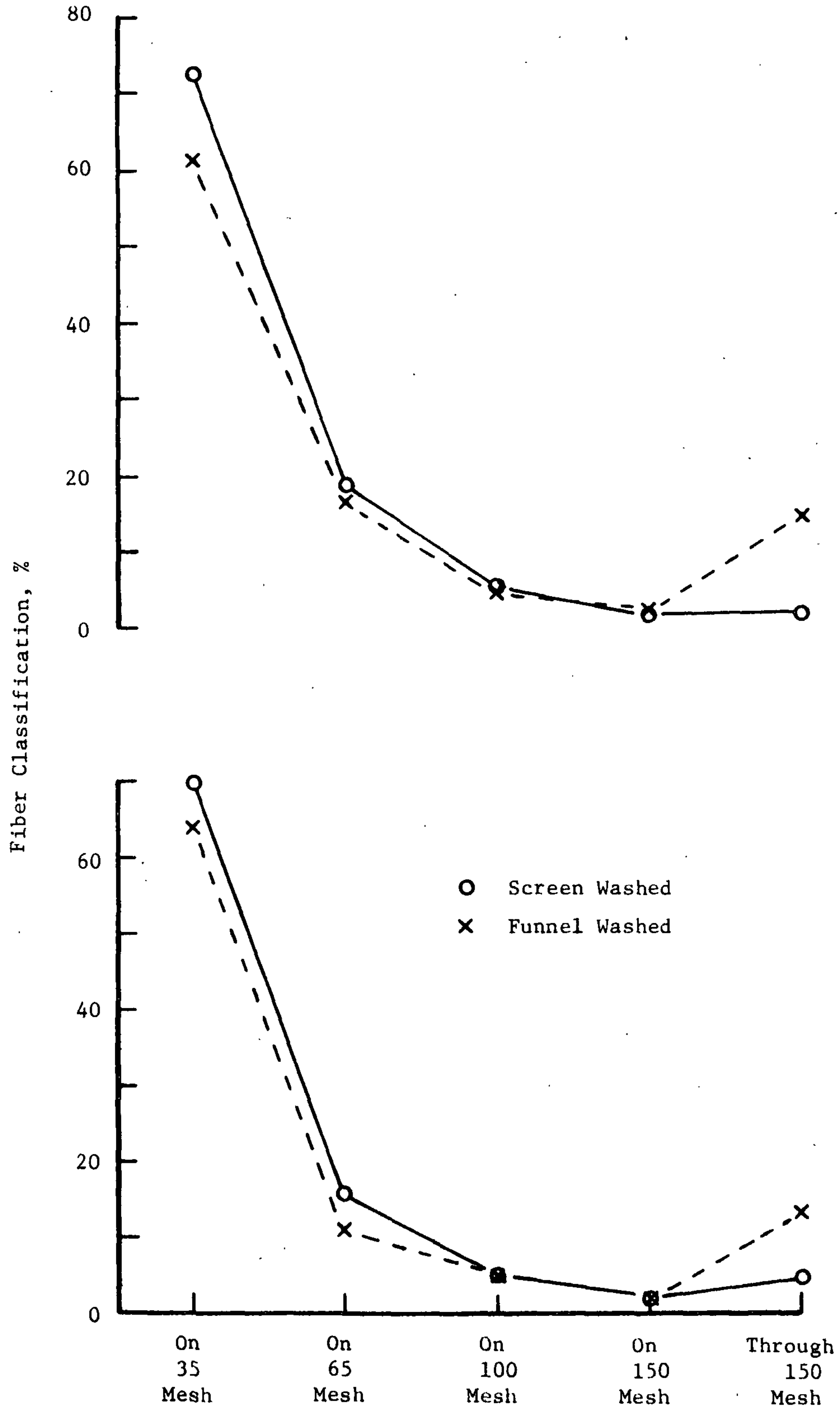

Figure 12. Effect of Treatment and Washing Conditions on Fiber Classification

TABLE VIII

EFFECT OF GREEN LIQUOR TREATMENTS IN ASPLUND ON PHYSICAL PROPERTIES

Green Liquor, %	Treatment, wash	C.S. Freeness, mL	Basis Weight, lb/M ft^2	Caliper, mil	Density	Burst Factor	Modified Ring Comp. Factor	Tensile Factor	Et Factor	Tear Factor	Stretch, %	TEA, ft-lb/sq ft	Concora, psi
							0 Minute Beating						
--	Untreated	652	13.6	5.8	2.34	1.27	0.288	0.90	124.8	6.44	1.82	1.9	14.8
0	Asplund, screen	730	14.2	6.2	2.30	0.96	0.156	0.68	105.6	6.91	1.84	1.6	9.5
3	Asplund, screen	730	14.0	5.6	2.48	1.44	0.225	0.90	120.1	7.70	2.43	2.7	15.3
0	Asplund, funnel	565	13.4	5.3	2.53	1.38	0.294	0.78	101.2	7.05	2.64	2.6	16.5
3	Asplund, funnel	515	13.6	4.9	2.81	1.94	0.323	1.02	123.0	7.07	3.15	3.9	25.7
							5 Minute Beating						
--	Untreated	592	13.8	5.5	2.52	1.68	0.322	1.15	144.7	6.04	2.09	2.8	20.5
0	Asplund, screen	700	14.2	5.8	2.43	1.50	0.215	0.98	131.8	7.50	2.21	2.7	14.8
3	Asplund, screen	690	14.3	5.4	2.67	1.93	0.245	1.13	142.3	7.22	2.52	3.5	20.9
0	Asplund, funnel	520	13.3	5.1	2.60	1.72	0.298	1.00	118.6	6.82	2.98	3.5	21.9
3	Asplund, funnel	440	13.3	4.7	2.82	2.23	0.330	1.19	135.4	6.50	3.08	4.2	30.0
							10 Minute Beating						
--	Untreated	528	13.6	5.2	2.62	2.01	0.354	1.31	151.8	5.73	2.20	3.4	26.0
0	Asplund, screen	670	14.2	5.6	2.53	1.98	0.258	1.14	131.9	7.06	2.31	3.2	20.8
3	Asplund, screen	650	14.2	5.2	2.74	2.25	0.274	1.31	149.8	6.47	2.49	3.9	26.9
0	Asplund, funnel	455	13.4	5.0	2.69	2.10	0.337	1.13	129.9	6.05	2.91	3.8	26.2
3	Asplund, funnel	400	13.5	4.6	2.95	2.50	0.362	1.40	152.4	5.70	3.33	5.4	34.0
							20 Minute Beating						
--	Untreated	372	13.8	5.0	2.80	2.57	0.361	1.52	165.6	5.39	2.49	4.4	32.0
0	Asplund, screen	550	14.2	5.3	2.67	2.52	0.267	1.42	156.2	6.02	2.52	4.3	29.5
3	Asplund, screen	510	14.4	5.1	2.84	2.77	0.292	1.58	171.1	5.98	2.64	5.1	34.7
0	Asplund, funnel	340	13.6	4.8	2.85	2.42	0.331	1.38	149.2	5.66	3.08	5.0	34.1
3	Asplund, funnel	240	13.4	4.4	3.02	2.84	0.341	1.57	167.6	5.27	3.17	5.7	35.9
							30 Minute Beating						
--	Untreated	218	13.2	4.6	2.82	2.88	0.364	1.72	179.4	4.99	2.56	4.8	33.8
0	Asplund, screen	405	14.3	5.1	2.78	2.81	0.315	1.65	176.0	5.68	2.59	5.1	35.4
3	Asplund, screen	360	14.1	4.8	2.92	3.20	0.309	1.73	183.8	5.50	2.72	5.5	38.3
0	Asplund, funnel	210	13.1	4.4	2.95	2.75	0.355	1.60	167.7	4.95	3.07	5.5	36.8
3	Asplund, funnel	140	13.3	4.2	3.17	3.02	0.343	1.71	178.7	4.71	2.88	5.5	35.6

Note: All factors were obtained by dividing the test results, usually in English units, by the basis weight in lb/1000 ft^2. The Concora tests were carried out on 26 lb/1000 ft^2 sheets.

TABLE IX

EFFECT OF GREEN LIQUOR TREATMENTS IN THE ASPLUND MILL
(Referenced to Untreated OCC)

	Untreated OCC	Flat Screen Washed				Funnel Washed			
		Asplund Control	Diff., %[a]	3% Green Liquor	Diff., %[a]	Asplund Control	Diff., %[a]	3% Green Liquor	Diff., %[a]
600 mL C.S. Freeness									
Burst factor	1.60	2.38	+48.8	2.53	+58.1	--[b]	--	--[b]	--
Ring comp. factor	0.318	0.271	-14.8	0.280	-11.9	--	--	--	--
Tensile factor	1.10	1.31	+19.1	1.42	+29.1	--	--	--	--
Tear factor	6.08	6.33	+ 4.1	6.44	+ 5.9	--	--	--	--
500 mL C.S. Freeness									
Burst factor	2.13	2.73	+28.2	2.94	+38.0	1.83	-14.1	1.99	-6.6
Ring comp. factor	0.355	0.293	-17.5	0.292	-17.7	0.323	- 9.0	0.325	-8.5
Tensile factor	1.36	1.50	+10.3	1.58	+16.2	1.05	-22.8	1.06	-22.1
Tear factor	5.63	5.82	+ 3.4	5.87	+ 4.3	6.44	+14.4	6.96	+23.6
350 mL C.S. Freeness									
Burst factor	2.65	--[c]	--	3.21	+21.1	2.50	- 5.7	2.62	-1.1
Ring comp. factor	0.363	--	--	0.310	-14.6	0.344	- 5.2	0.338	-6.9
Tensile factor	1.59	--	--	1.74	+ 9.4	1.38	-13.2	1.39	-12.6
Tear factor	5.26	--	--	5.48	+ 4.2	5.54	+ 5.3	5.92	+12.5

[a] Based on untreated OCC as reference.

[b] Initial freeness below 600 mL.

[c] Freeness after 30-min beating above 350 mL.

Note: All factors obtained by dividing the test value by the weight in lb/1000 ft^2.

TABLE X

EFFECT OF GREEN LIQUOR TREATMENTS IN THE ASPLUND MILL
(Referenced to Asplund Controls)

	Untreated OCC	Flat Screen Washed			Funnel Washed		
		Asplund Control	3% Green Liquor	Diff., %[a]	Asplund Control	3% Green Liquor	Diff., %[a]
600 mL C.S. Freeness							
Burst factor	1.60	2.38	2.53	+6.3	--[b]	--[b]	--
Mod. ring factor	0.318	0.271	0.280	+3.3	--	--	--
Tensile factor	1.10	1.31	1.42	+8.4	--	--	--
Tear factor	6.08	6.33	6.44	+1.7	--	--	--
500 mL C.S. Freeness							
Burst factor	2.13	2.73	2.94	+7.7	1.83	1.99	+8.7
Mod. ring factor	0.355	0.293	0.292	-0.3	0.323	0.325	+0.6
Tensile factor	1.36	1.50	1.58	+5.3	1.05	1.06	+1.0
Tear factor	5.63	5.82	5.87	+0.9	6.44	6.96	+8.1
350 mL C.S. Freeness							
Burst factor	2.65	--[c]	3.21	--[c]	2.50	2.62	+4.8
Mod. ring factor	0.363	--	0.310	--	0.344	0.338	-1.7
Tensile factor	1.59	--	1.74	--	1.38	1.39	+0.7
Tear factor	5.26	--	5.48	--	5.54	5.92	+6.9

[a]Based on Asplund controls as reference.

[b]Initial freeness below 600 mL.

[c]Freeness after 30-min beating above 350 mL.

Note: Factors obtained by dividing the test value by the weight in lb/1000 ft^2.

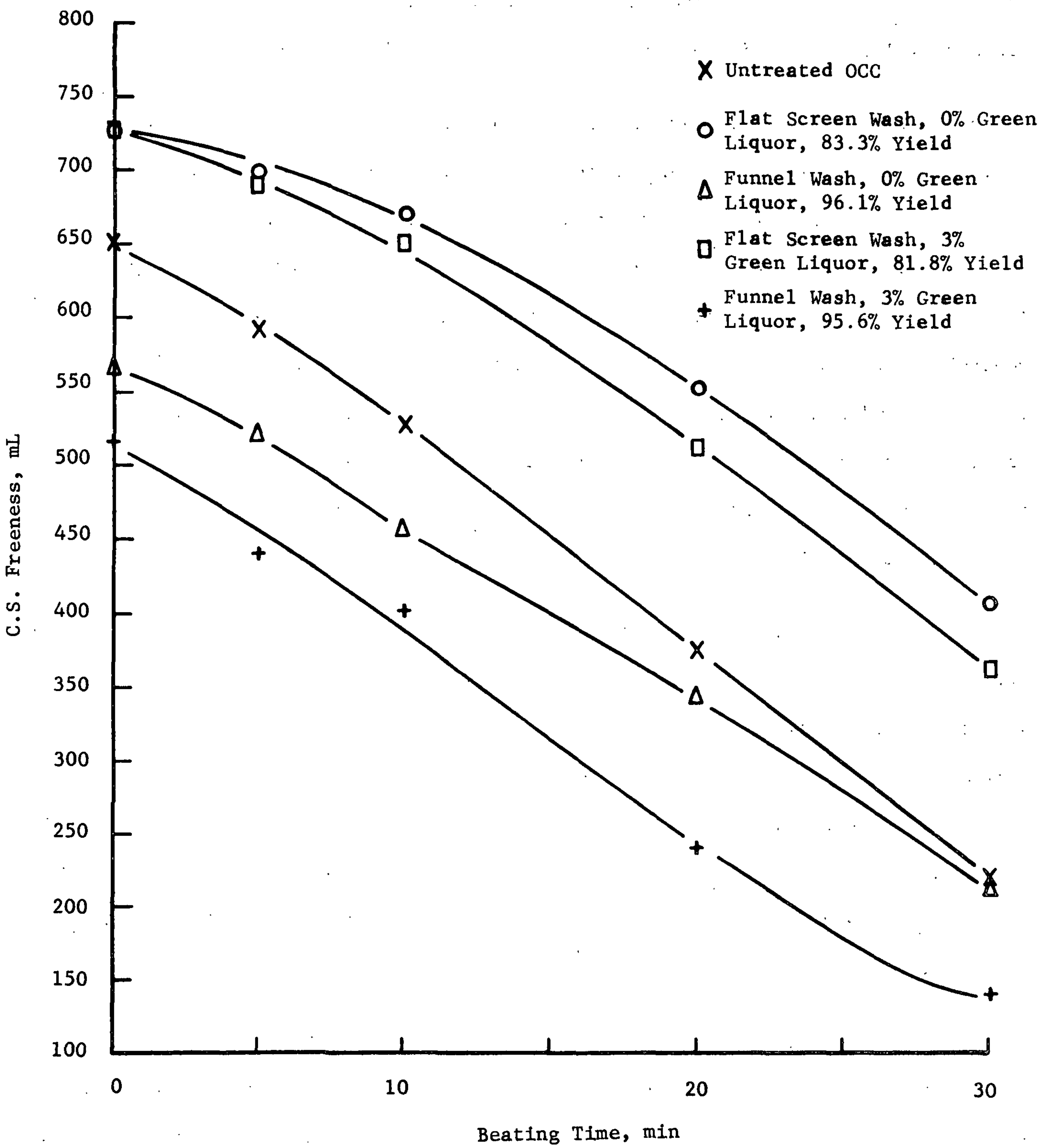

Figure 13. Effect of Green Liquor Treatments in the Asplund on Freeness

Asplund control but considerably higher than the untreated OCC. Thus, the loss of fines markedly increased the freeness of both the Asplund control and treated stock.

The bursting strength results in Fig. 14 indicate that the funnel washed Asplund control exhibited lower strength than the untreated OCC at a given freeness. This loss of strength may be attributed to the effect of the Asplund conditions on fiber characteristics and in reducing the freeness. After treatment with green liquor the funnel washed stock gave somewhat higher strengths than its Asplund control. For example, the percent improvement at 500 mL freeness was 8.7% relative to the Asplund control (see Table X). However, the burst strength of the funnel washed treated stock was generally lower than that of the untreated OCC. At 500 mL freeness, the burst strength of the treated stock was 6.6% lower than that of the untreated OCC (Table IX).

Figure 14 also shows that the screen washed stocks gave considerably higher bursting strengths than the untreated OCC at a given freeness as a result of the loss in fines and attendant increase in freeness. For this case the bursting strength of the Asplund control was about 28% higher than the untreated OCC at 500 mL freeness (Table IX). Treatment with green liquor effected a further improvement in bursting strength of about 8% over its Asplund control at 500 mL freeness. Thus the loss of the very fine matter in the stock markedly improved burst at a given freeness.

For comparison purposes the beater evaluation burst results on the virgin kraft primary stock are also shown in Fig. 14 (note the beater evaluation data are in Appendix I). At constant freeness the burst results for the untreated OCC and Asplund treatments where fines were retained were well below the virgin

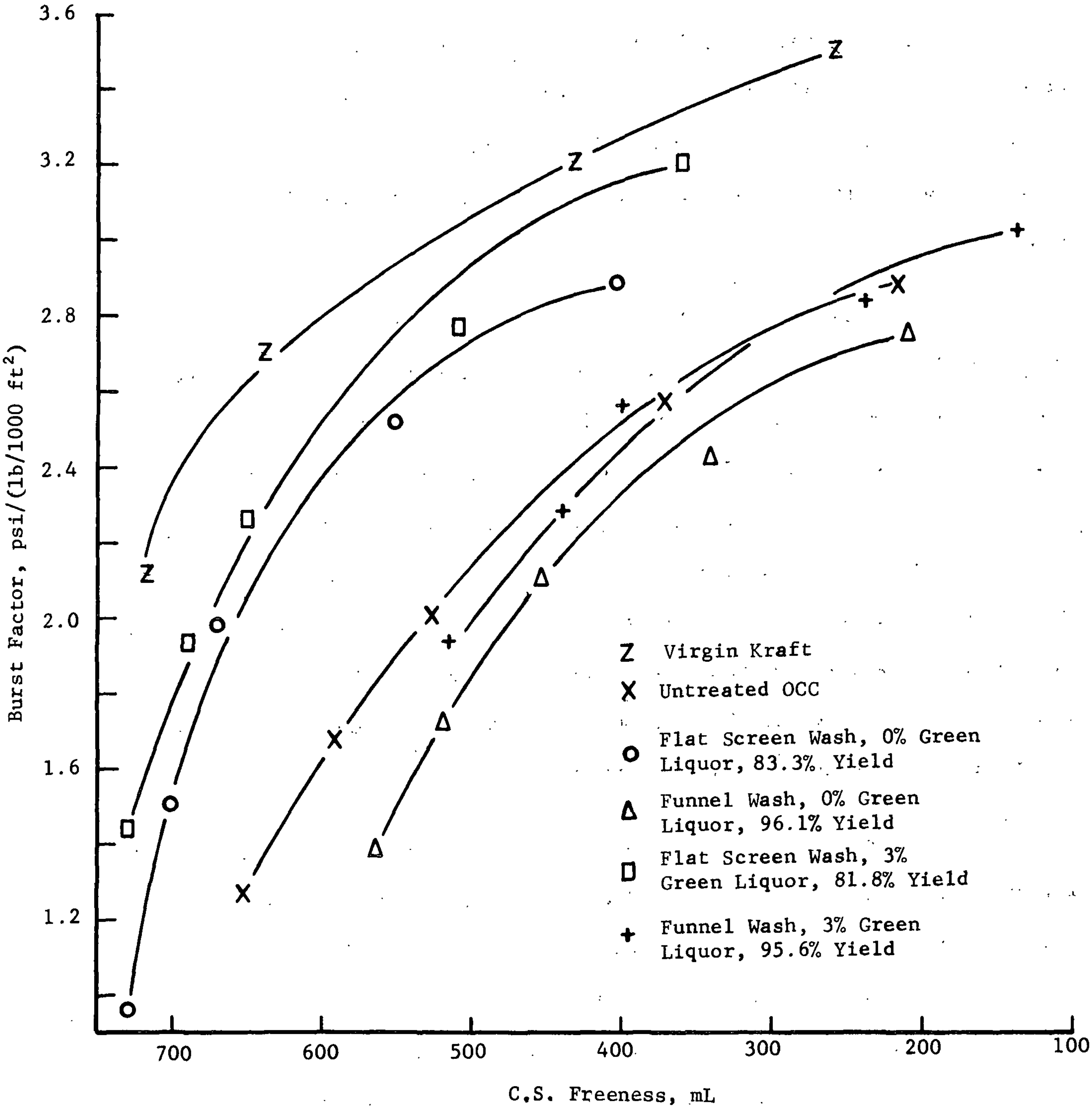

Figure 14. Effect of Green Liquor Treatments in the Asplund on Burst

kraft burst levels. The burst results for the screen washed Asplund trials approached those for virgin kraft.

The above results indicate that the fines, e.g., material passing 150 mesh — have a major effect on drainage and strength. It appears that improvements in OCC performance could be attained if the fines could be economically removed, recovered and disposed. This is also illustrated by the tensile results shown in Fig. 15.

At constant density Fig. 16 shows that the burst results on the funnel washed Asplund control were slightly lower than for untreated OCC. Green liquor treatment followed by funnel washing (fines retained) tended to increase the density but resulted in slightly lower burst strength at a given density. After screen washing (fines removed) the Asplund control tended to exhibit slightly lower densities and higher burst values at a given density than the untreated OCC. For this washing case where fines were removed the burst results for the green liquor treatment were about the same as obtained on untreated OCC at a given density. After removal of fines the burst results for the Asplund control were only slightly lower than the results obtained on the virgin kraft pulp.

The tensile vs. density results in Fig. 17 are similar to those obtained for bursting strength. At a given density the funnel washed Asplund control stock exhibited considerably lower tensile strength than the untreated OCC. The green liquor treatment followed by funnel washing to retain fines did not improve tensile strength over that of its corresponding Asplund control. The screen washed Asplund control trials where loss of fines occurred exhibited about the same tensile strengths as the untreated OCC. Under these conditions the green liquor treatment tended to increase density at a given tensile strength.

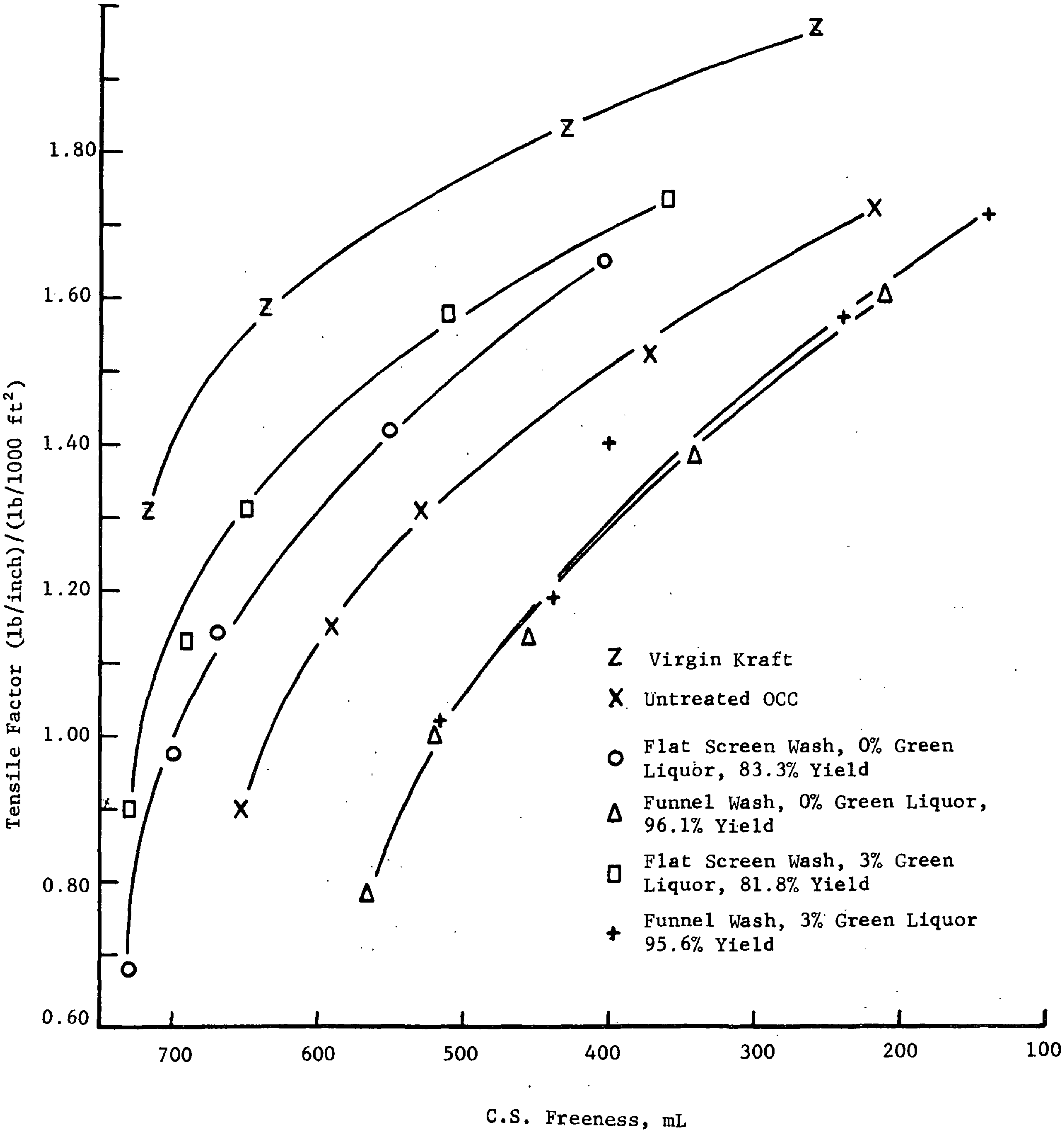

Figure 15. Effect of Green Liquor Treatments in the Asplund on Tensile

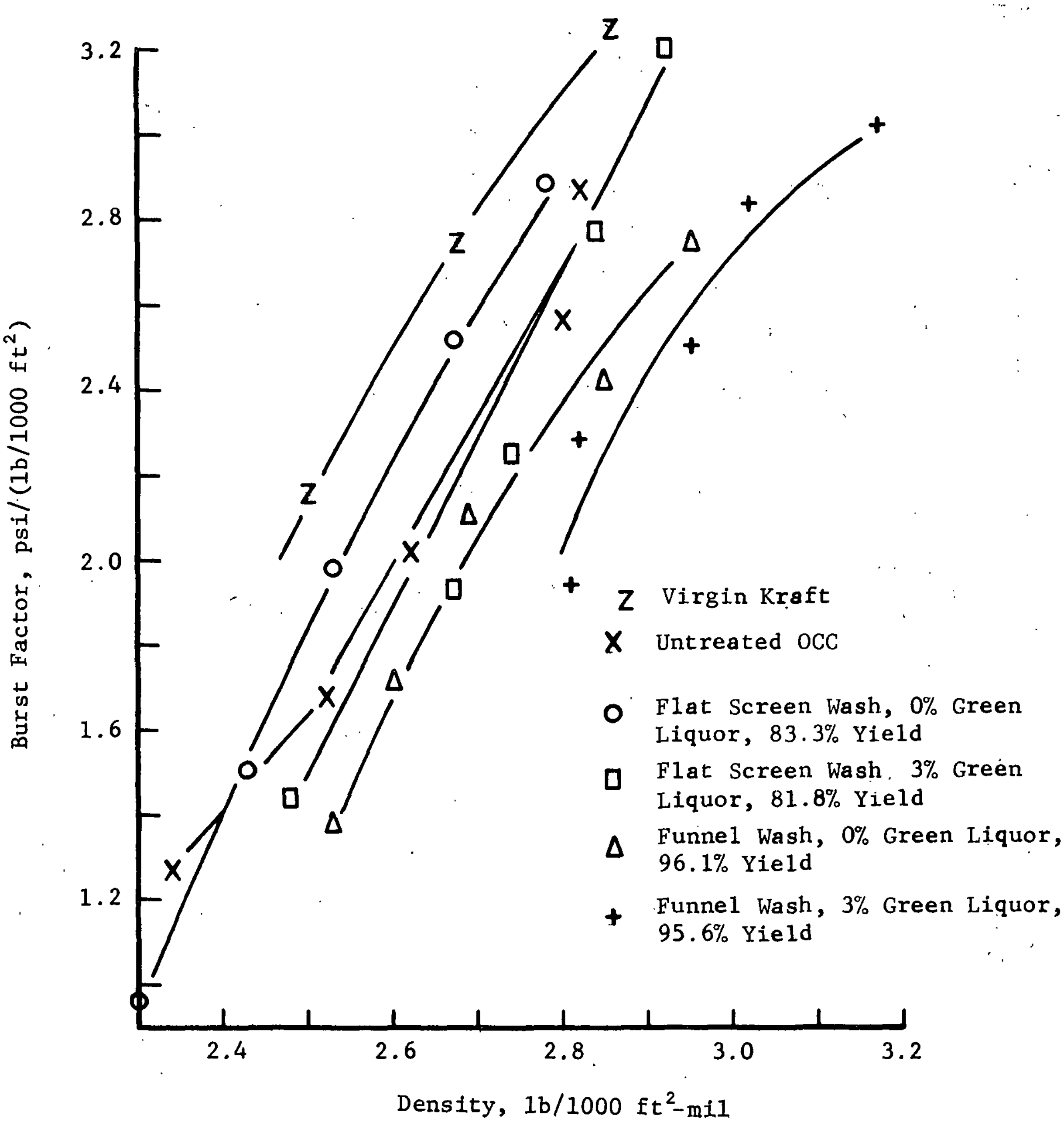

Figure 16. Effect of Green Liquor Treatments in the Asplund on Burst vs. Density Relationships

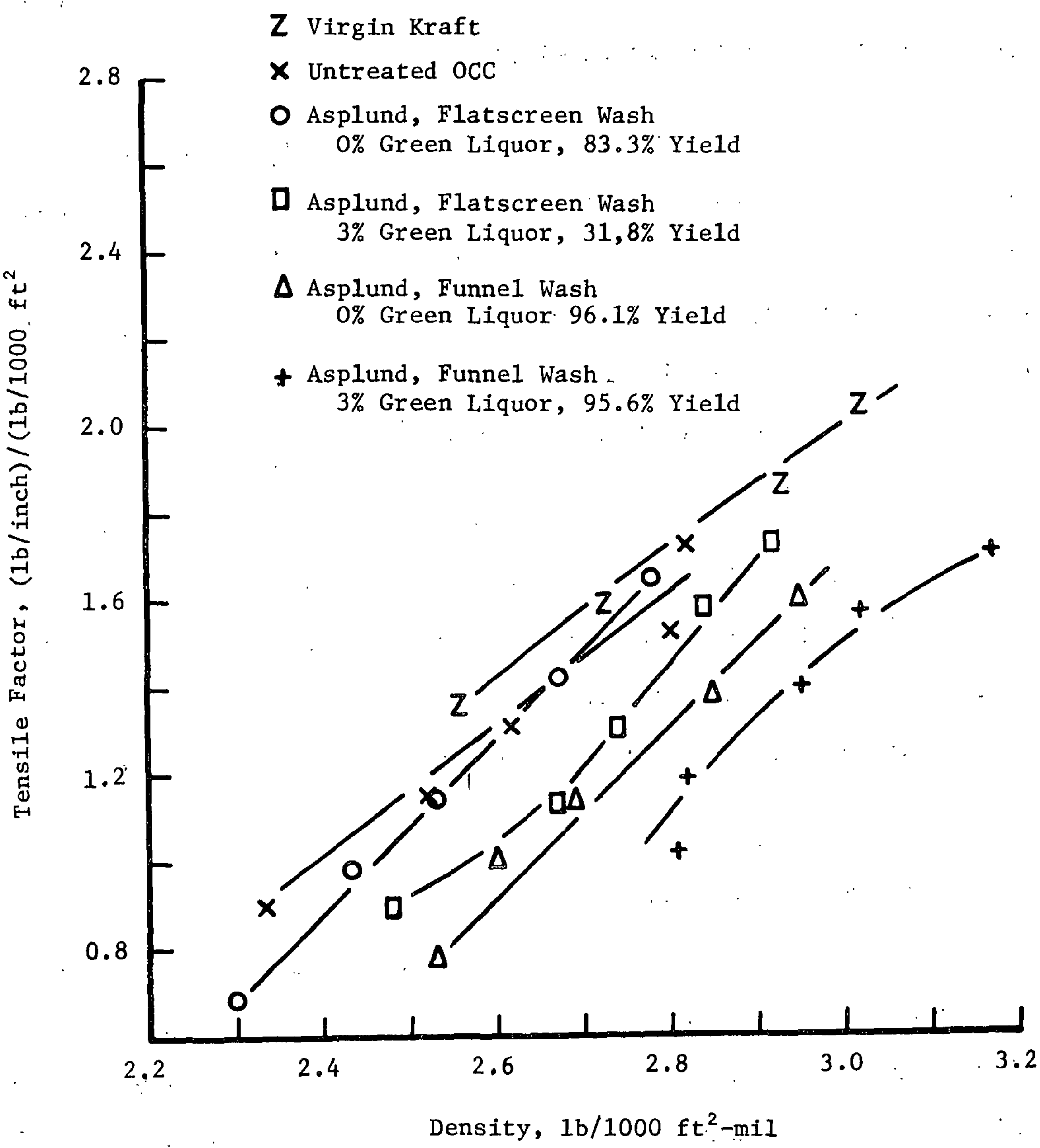

Figure 17. Effect of Green Liquor Treatments in the Asplund on Tensile

The tear factor vs. freeness results in Fig. 18 show that the funnel washed green liquor stock exhibited higher strengths than the corresponding Asplund control or untreated OCC at constant freeness. At the lower freeness levels the results for the funnel treated green liquor stock were similar to those for virgin kraft. The tear results for the screen washed green liquor stocks were slightly higher than those for the untreated OCC.

Figure 19 shows that the green liquor treatments generally did not improve modified ring compression strength over that of the Asplund controls at constant density. When fines were retained the Asplund control and green liquor treatment results were slightly below those for the untreated OCC and virgin kraft although shifted toward higher density levels. At a constant density the lowest results tended to be obtained with the Asplund trials where fines were lost.

Figure 20 shows that at a given burst factor the edgewise compression strength results for the OCC, virgin kraft, funnel washed Asplund control and green liquor treated stocks with fines retained were roughly comparable. In contrast the removal of fines resulted in lower compression strengths than the other stocks for both the Asplund control and green liquor treated stocks.

Tensile vs. tear relationships for the green liquor treatments are shown in Fig. 21. At a given tearing strength the highest tensile results were generally achieved in the Asplund trials where the fines were lost in the screen washing process. For this condition the control and green liquor treatment results followed essentially the same relationship. At constant tearing strength the tensile results for the funnel washed Asplund stocks were generally higher than for the untreated OCC but lower than those for the screen washed stocks. The

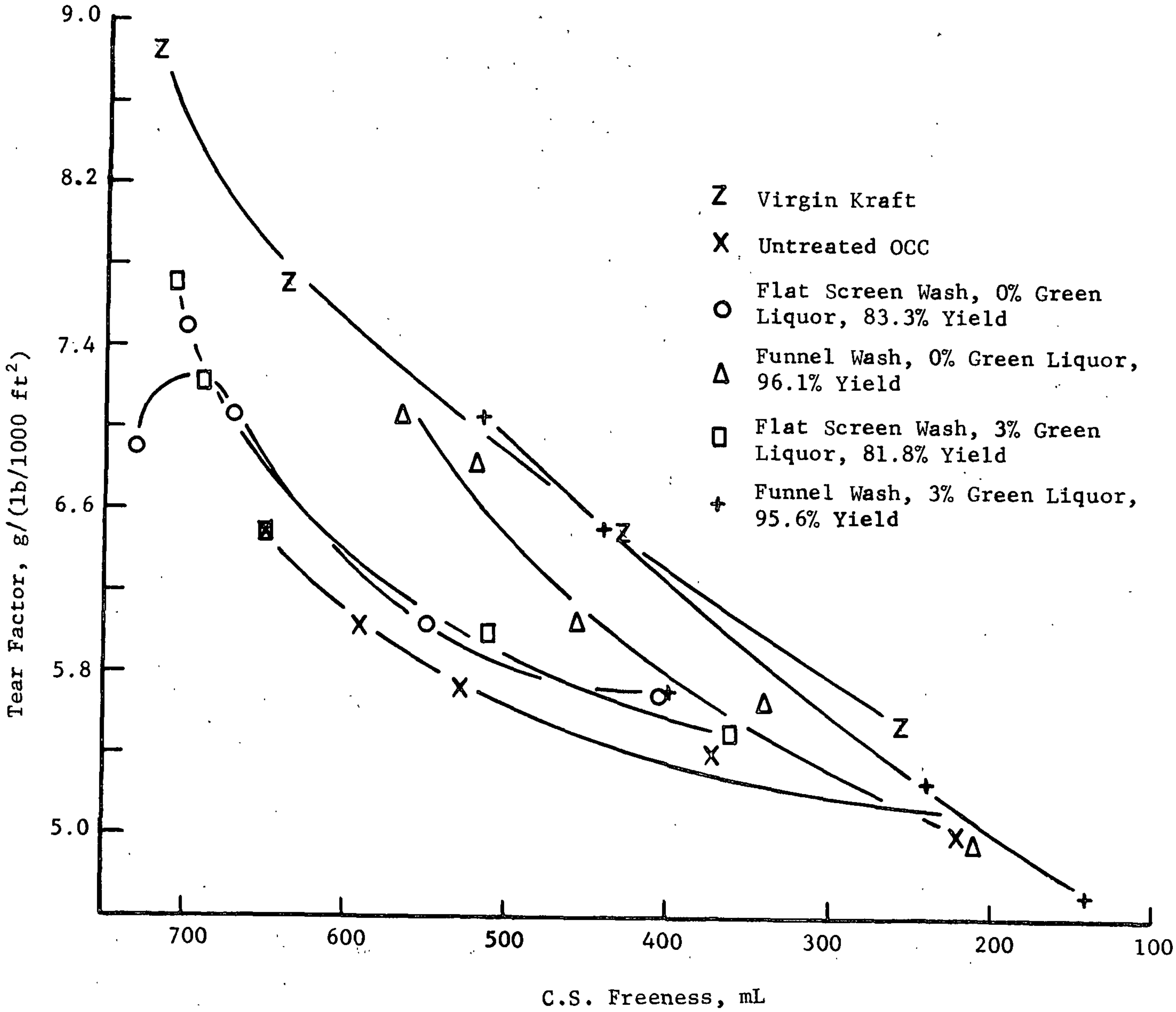

Figure 18. Effect of Green Liquor Treatments in the Asplund on Tear

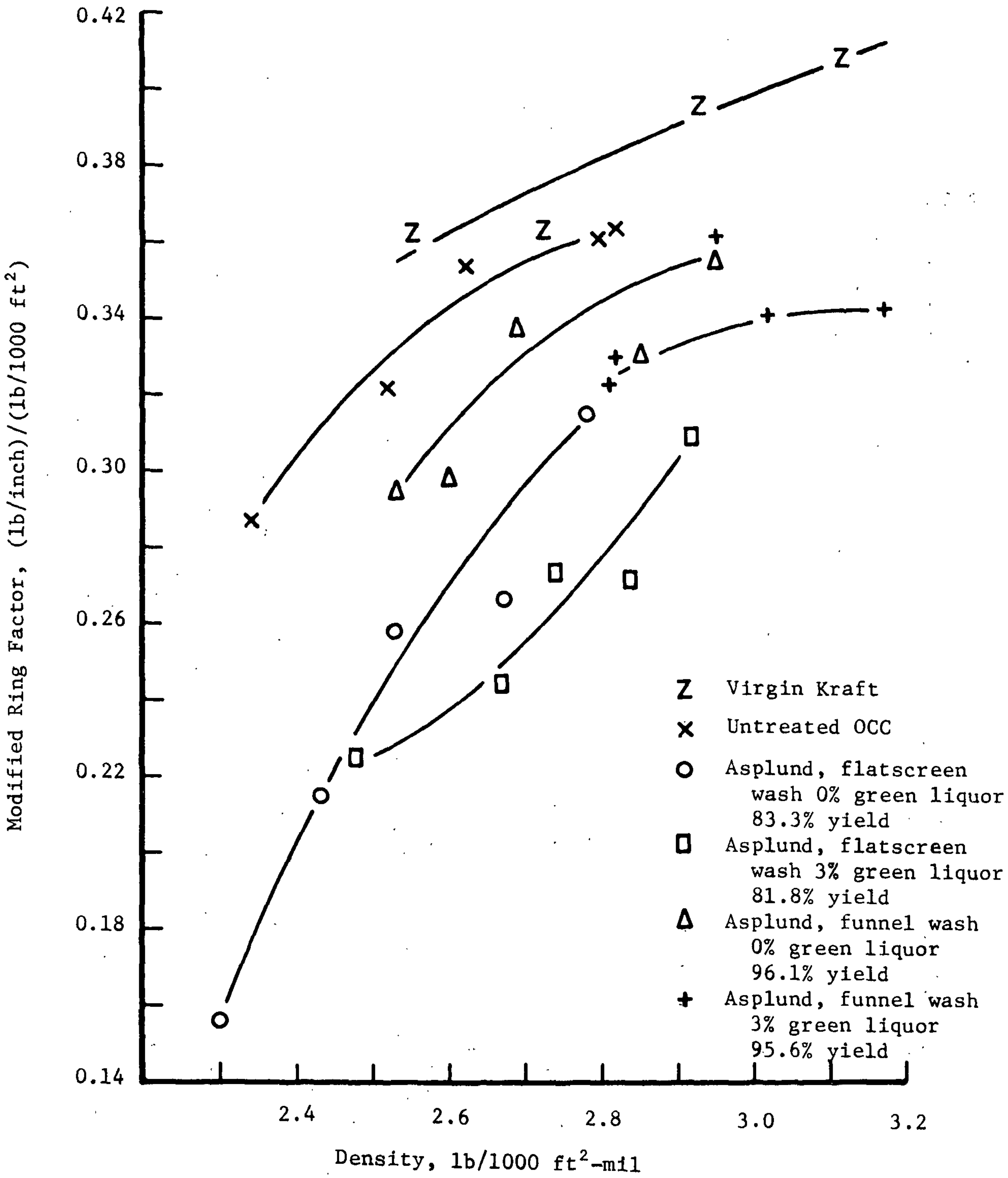

Figure 19. Effect of Green Liquor Treatments in the Asplund on Edgewise Compression

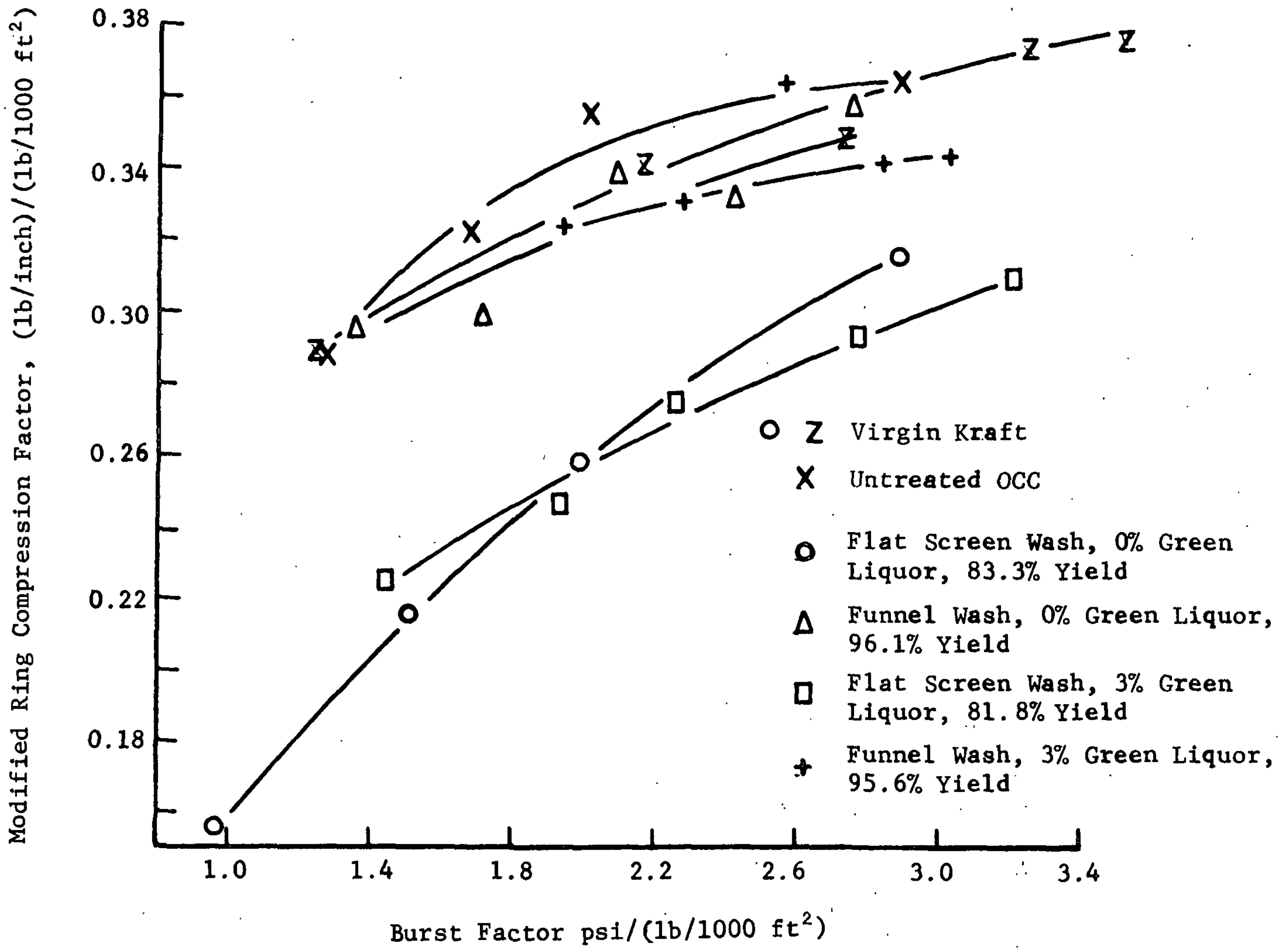

Figure 20. Effect of Green Liquor Treatments in the Asplund on Burst vs. Modified Ring Compression Relationships

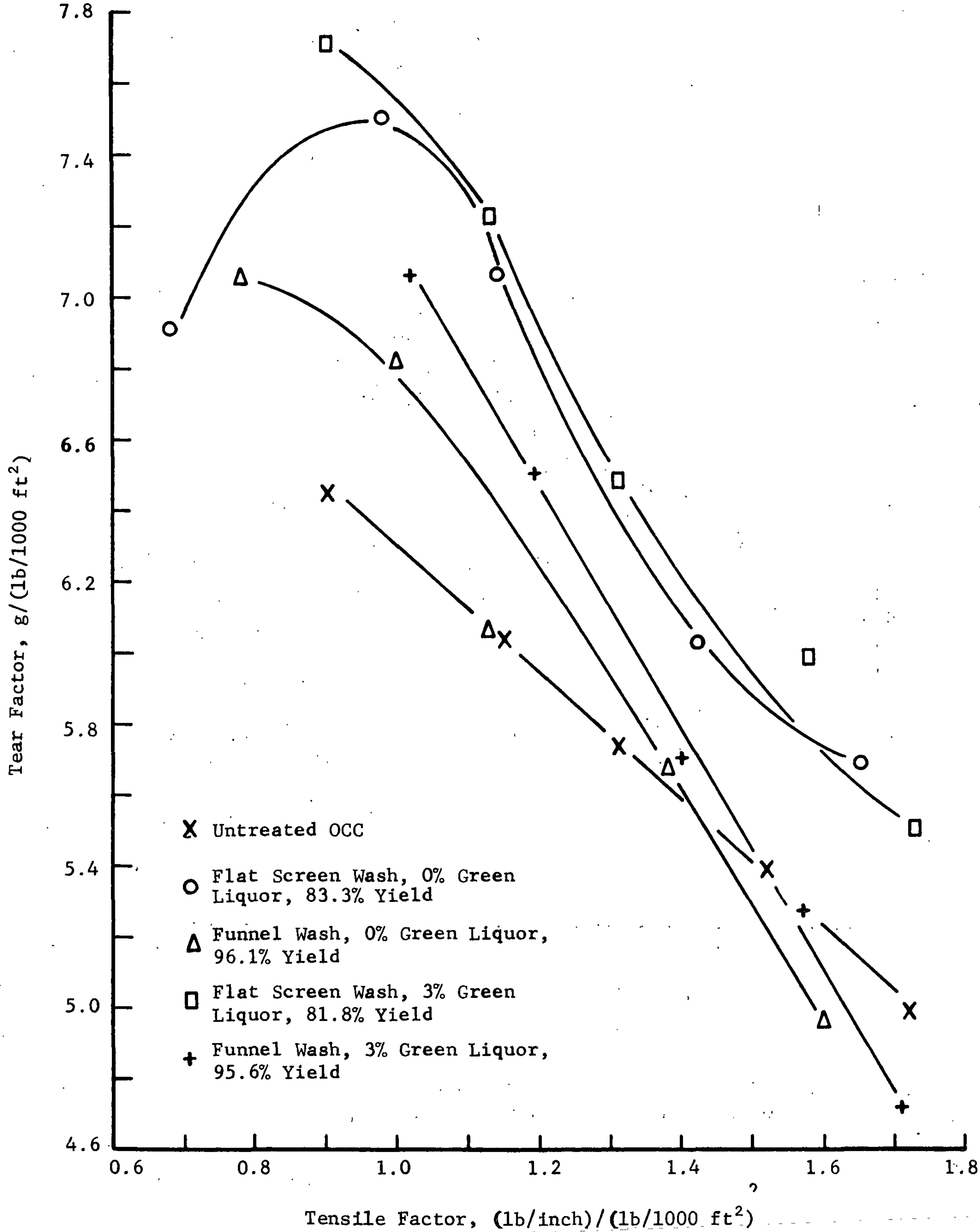

Figure 21. Effect of Green Liquor Treatments on the Asplund on Tensile vs. Tear Relationships

funnel washed green liquor treatment tensile results were slightly higher than those of its corresponding Asplund control at constant tear.

The virgin kraft results are not shown but would plot in the upper right of the graph. Thus, it appears that all of the Asplund treatments give lower tearing strength at a given tensile than the virgin kraft. This would be expected in view of the shorter hardwood fibers present in the OCC.

Briefly summarizing, the green liquor treatment results indicate the following:

Case 1 Fines retained by means of funnel washing

1. Asplund treatment with no chemical resulted in large freeness reductions of the control at equal beating times.

2. Green liquor treatment in the Asplund resulted in additional freeness losses.

3. At a given density the bursting strengths of the green liquor treated stocks were lower than either the Asplund control or untreated OCC. Thus at a given bursting strength the treated stock exhibited somewhat higher densities.

4. At constant freeness the bursting strengths of the green liquor treated stock were generally lower than that of the untreated OCC. At 500 mL freeness the burst strength of the treated stock was 6.6% lower than that of the untreated OCC. However, the treated stock did show some improvement relative to the Asplund control. At constant freeness the tensile results for

the green liquor treated stocks were considerably lower than for the untreated OCC.

5. The edgewise compression results achieved with green liquor treatment in the Asplund tended to be lower than obtained on the untreated OCC at a given density. They were about the same as obtained on the Asplund control but were achieved at higher densities.

6. At constant bursting strength the green liquor treated stock exhibited edgewise compression strengths which were about comparable to those for untreated OCC and the Asplund control.

Case 2 Fines removed in screen washing process

1. The Asplund control and green liquor treated stocks exhibited materially higher freeness values than the untreated OCC at equal beating times. This would be expected due to the loss of fines.

2. At a given density the bursting strength of the Asplund control was higher than obtained on the untreated OCC. After treatment with green liquor the bursting strength was about the same as obtained on untreated OCC at a given density. However the edgewise compression strengths were slightly lower than obtained on untreated OCC.

3. At constant freeness the tensile and bursting strengths of the green liquor treated stock were slightly higher than the corresponding Asplund control and much higher than the strengths achieved with the untreated OCC.

4. At constant freeness the green liquor treated stocks exhibited somewhat lower edgewise compression strengths than the untreated OCC. They were generally about the same as obtained in the corresponding Asplund control.

5. At constant bursting strength the loss in fines resulted in slightly lower edgewise compression strengths for the Asplund control and green liquor treated stocks.

Caustic Soda Beater Evaluation Results

The beater evaluation results on the caustic soda treatments in the Asplund are tabulated in Table XI. Various test properties are compared at 600, 500 and 350 mL C.S. freeness in Tables XII and XIII. In Table XII the differences are referenced to the properties of the untreated OCC. In Table XIII the effects of the caustic soda treatment are referred to the untreated Asplund controls.

In general, the caustic soda treatments in the Asplund gave results which were similar to those obtained with green liquor. Some differences in effects were obtained which are probably due in part to the more drastic Asplund conditions employed with the caustic soda as well as chemical reactivity differences between green liquor and caustic soda.

Figure 22 shows that the funnel washed Asplund control with fines retained exhibited freeness values which generally ranged between 50-90 mL lower than the

TABLE XI

EFFECT OF CAUSTIC SODA TREATMENTS IN THE ASPLUND

NaOH, %	Treatment, wash	C.S. Freeness mL	Basis Weight, lb/M ft²	Caliper, mil	Density	Burst Factor	Modified Ring Comp. Factor	Tensile Factor	Et Factor	Tear Factor	Stretch, %	TEA, ft lb/ft²	Concora, psi
						0 Minute Beating							
0	Untreated, OCC	652	13.6	5.8	2.34	1.27	0.288	0.90	124.8	6.44	1.82	1.9	14.8
0	Asplund, screen	712	13.2	5.6	2.35	1.01	0.232	0.66	98.0	7.42	2.04	1.6	10.3[a]
3	Asplund, screen	702	13.3	5.2	2.57	1.58	0.266	0.90	112.5	7.70	2.72	3.0	19.4[a]
0	Asplund, funnel	570	13.4	5.6	2.40	1.40	0.264	0.76	99.4	7.46	2.73	2.6	15.7
3	Asplund, funnel	525	13.2	5.0	2.62	1.92	0.266	1.02	120.8	7.22	3.20	3.9	25.5
						5 Minute Beating							
0	Untreated, OCC	592	13.8	5.5	2.52	1.68	0.322	1.15	144.7	6.04	2.09	2.8	20.5
0	Asplund, screen	675	13.2	5.4	2.45	1.54	0.292	0.94	122.4	7.12	2.44	2.7	15.6[a]
3	Asplund, screen	650	13.6	5.0	2.72	2.10	0.310	1.20	135.2	6.82	2.86	4.0	25.9[a]
0	Asplund, funnel	502	13.4	5.2	2.54	1.86	0.290	1.01	120.8	6.43	2.90	3.5	21.6
3	Asplund, funnel	475	13.3	4.8	2.78	2.36	0.294	1.26	135.3	6.18	3.28	4.8	30.2
						10 Minute Beating							
0	Untreated, OCC	528	13.6	5.2	2.62	2.01	0.354	1.31	151.8	5.73	2.20	3.4	26.0
0	Asplund, screen	640	13.4	5.3	2.52	1.86	0.330	1.12	135.8	6.69	2.54	3.3	21.0[a]
3	Asplund, screen	590	13.3	4.6	2.88	2.44	0.310	1.36	144.3	6.32	2.93	4.5	28.0[a]
0	Asplund, funnel	455	13.4	5.1	2.64	2.18	0.322	1.18	132.9	6.03	2.94	4.2	26.9
3	Asplund, funnel	412	13.2	4.6	2.86	2.69	0.298	1.42	149.2	5.92	3.22	5.2	33.0
						20 Minute Beating							
0	Untreated, OCC	372	13.8	5.0	2.80	2.57	0.361	1.52	165.6	5.39	2.49	4.4	32.0
0	Asplund, screen	512	13.6	5.0	2.68	2.48	0.358	1.36	147.6	6.08	2.77	4.4	23.1[a]
3	Asplund, screen	432	13.4	4.5	2.98	2.84	0.325	1.60	164.6	5.68	2.98	5.4	34.3[a]
0	Asplund, funnel	320	13.4	4.9	2.75	2.62	0.340	1.45	147.4	5.42	3.09	5.2	33.6
3	Asplund, funnel	235	13.4	4.6	2.96	2.96	0.324	1.55	163.9	5.28	3.03	5.6	38.0
						30 Minute Beating							
0	Untreated, OCC	218	13.2	4.6	2.82	2.88	0.364	1.72	179.4	4.99	2.56	4.8	33.8
0	Asplund, screen	352	13.6	4.8	2.80	2.70	0.378	1.58	164.6	5.58	2.86	5.2	31.0[a]
3	Asplund, screen	258	13.6	4.3	3.18	3.24	0.322	1.76	177.4	5.37	2.98	6.1	38.8[a]
0	Asplund, funnel	195	13.4	4.6	2.91	3.00	0.346	1.61	164.2	4.93	2.93	5.5	35.3
3	Asplund, funnel	138	13.3	4.4	3.06	3.20	0.328	1.78	176.6	4.70	3.15	6.4	39.2

[a]Single trial.

Note: All factors obtained by dividing the test result by the basis weight in lb/M ft².

TABLE XII

EFFECT OF CAUSTIC TREATMENTS IN THE ASPLUND MILL
(Referenced to Untreated OCC)

	Untreated OCC	Flat Screen Washed				Funnel Washed			
		Asplund Control	Diff., %[a]	3% NaOH	Diff., %[a]	Asplund Control	Diff., %[a]	3% NaOH	Diff., %[a]
600 mL C.S. Freeness									
Burst factor	1.60	2.07	+29.4	2.34	+46.2	--[b]	--	--	--
Ring comp. factor	0.318	0.341	+ 7.2	0.307	- 3.5	--	--	--	--
Tensile factor	1.10	1.22	+10.9	1.32	+20.0	--	--	--	--
Tear factor	6.08	6.50	+ 6.9	6.43	+ 5.8	--	--	--	--
500 mL C.S. Freeness									
Burst factor	2.13	2.53	+18.8	2.77	+30.0	1.87	-12.2	2.17	+ 1.9
Ring comp. factor	0.355	0.362	+ 2.0	0.323	- 9.0	0.293	-17.5	0.274	-22.8
Tensile factor	1.36	1.44	+ 5.9	1.56	+14.7	1.02	-25.0	1.12	-17.6
Tear factor	5.63	6.06	+ 7.6	5.91	+ 5.0	6.42	+14.0	6.57	+16.7
350 mL C.S. Freeness									
Burst factor	2.65	2.91	+ 9.8	3.14	+18.5	2.61	- 1.5	2.90	+ 9.4
Ring comp. factor	0.363	0.379	+ 4.4	0.325	-10.5	0.335	- 7.7	0.310	-14.6
Tensile factor	1.59	1.58	- 0.6	1.73	+ 8.8	1.42	-10.7	1.53	- 3.8
Tear factor	5.26	5.64	+ 7.2	5.50	+ 4.6	5.48	+ 3.0	5.43	+ 3.2

[a] Based on untreated OCC as reference.

[b] Initial freeness below 600 mL.

Note: All factors obtained by dividing the test result by the basis weight in lb/1000 ft^2.

TABLE XIII

EFFECT OF CAUSTIC TREATMENTS IN THE ASPLUND MILL
(Referenced to Asplund Controls)

	Untreated OCC	Flat Screen Washed			Funnel Washed		
		Asplund Control	3% NaOH	Diff., %[a]	Asplund Control	3% NaOH	Diff., %[a]
600 mL C.S. Freeness							
Burst factor	1.60	2.07	2.34	+13.0	--[b]	--	--[b]
Mod. ring factor	0.318	0.341	0.307	-10.0	--	--	--
Tensile factor	1.10	1.22	1.32	+ 8.2	--	--	--
Tear factor	6.08	6.50	6.43	- 1.1	--	--	--
500 mL C.S. Freeness							
Burst factor	2.13	2.53	2.77	+ 9.5	1.87	2.17	+16.0
Mod. ring factor	0.355	0.362	0.323	-10.8	0.293	0.274	- 6.5
Tensile factor	1.36	1.44	1.56	+ 8.3	1.02	1.12	+ 9.8
Tear factor	5.63	6.06	5.91	- 2.5	6.42	6.57	+ 2.3
350 mL C.S. Freeness							
Burst factor	2.65	2.91	3.14	+ 7.9	2.61	2.90	+11.1
Mod. ring factor	0.363	0.379	0.325	-14.2	0.335	0.310	- 7.5
Tensile factor	1.59	1.58	1.73	+ 9.5	1.42	1.53	+ 7.7
Tear factor	5.26	5.64	5.50	- 2.5	5.48	5.43	- 0.9

[a]Based on Asplund controls as reference.

[b]Initial freeness below 600 mL.

Note: Factors obtained by dividing the test value by the basis weight in lb/1000 ft^2.

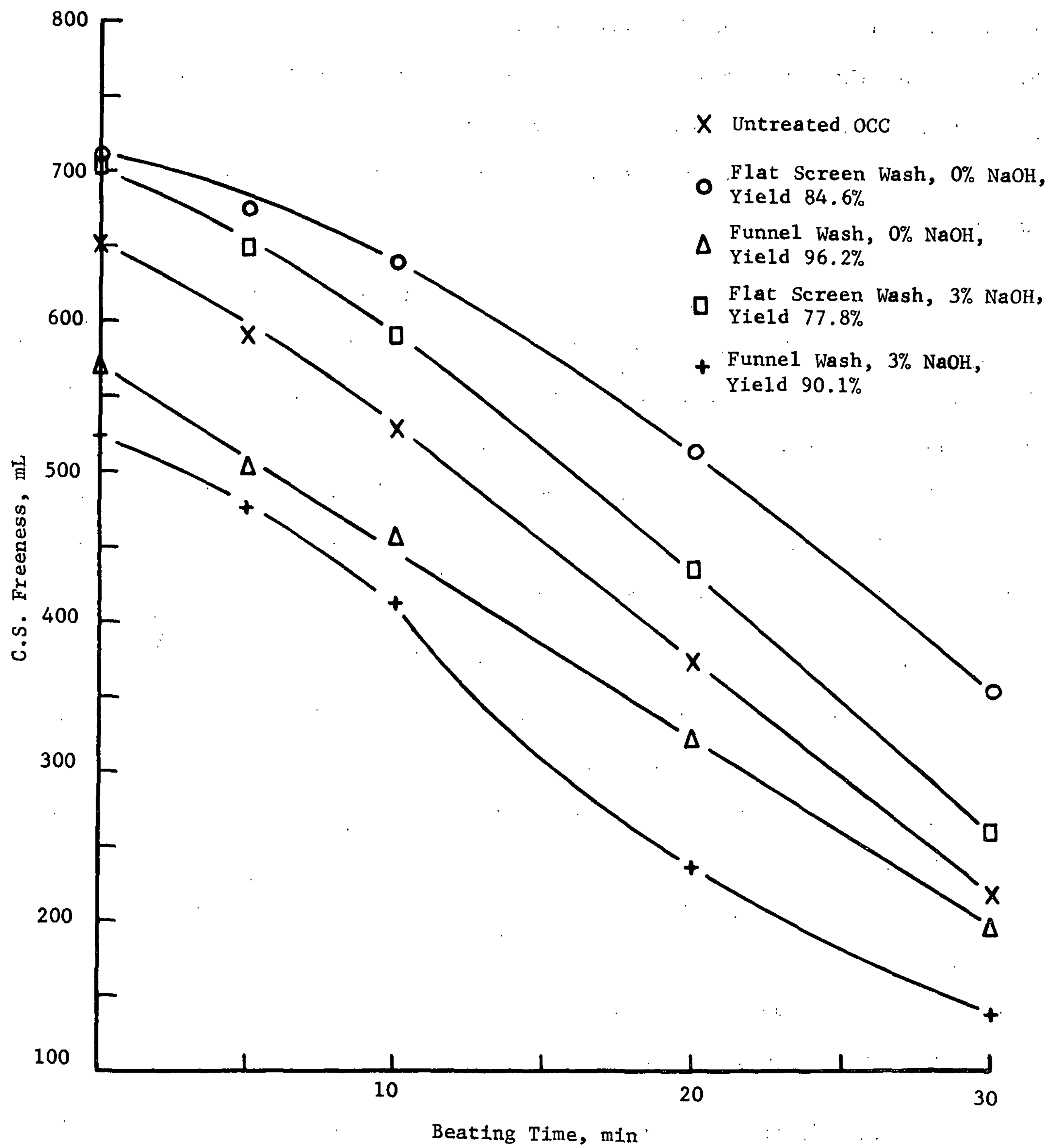

Figure 22. Effect of Caustic Soda Treatments in the Asplund on Freeness

untreated OCC which was merely defibered prior to beating. After treatment with caustic soda in the Asplund the funnel washed stocks exhibited even lower freeness. In most cases the freeness values were 100-120 mL C.S. freeness below the untreated OCC and 25-80 mL below the corresponding Asplund control. Thus, when the fines were retained the caustic treatments resulted in large freeness reductions at each beating interval.

As in the case of green liquor, the screen washed Asplund stocks exhibited considerably higher freeness values than the untreated OCC at equal beating times. This held true for both the Asplund control and caustic treated stocks. In this case, the caustic treatments resulted in freeness losses ranging from about 10-100 mL relative to the Asplund control. These losses tended to be somewhat greater than obtained with green liquor which may be due in part to the more drastic Asplund conditions used in the caustic soda trials.

The bursting strength results in Fig. 23 show that the funnel washed Asplund control with fines retained exhibited lower strength than the untreated OCC except at very low freenesses. After caustic treatment the funnel washed stock generally exhibited somewhat higher bursting strengths than its Asplund control and the untreated OCC at the lower freeness levels. At 500 mL freeness the burst strength of the treated stock was 16% higher than for the Asplund control and was slightly higher (+1.9%) than for the untreated OCC (see Tables XII and XIII). These changes were somewhat greater than obtained with green liquor. However, the yield was lower with caustic soda.

Figure 23 also shows that the screen washed stocks where fines were removed gave higher bursting strengths than the untreated OCC at a given freeness. For this case the bursting strength of the Asplund control was about 19% higher

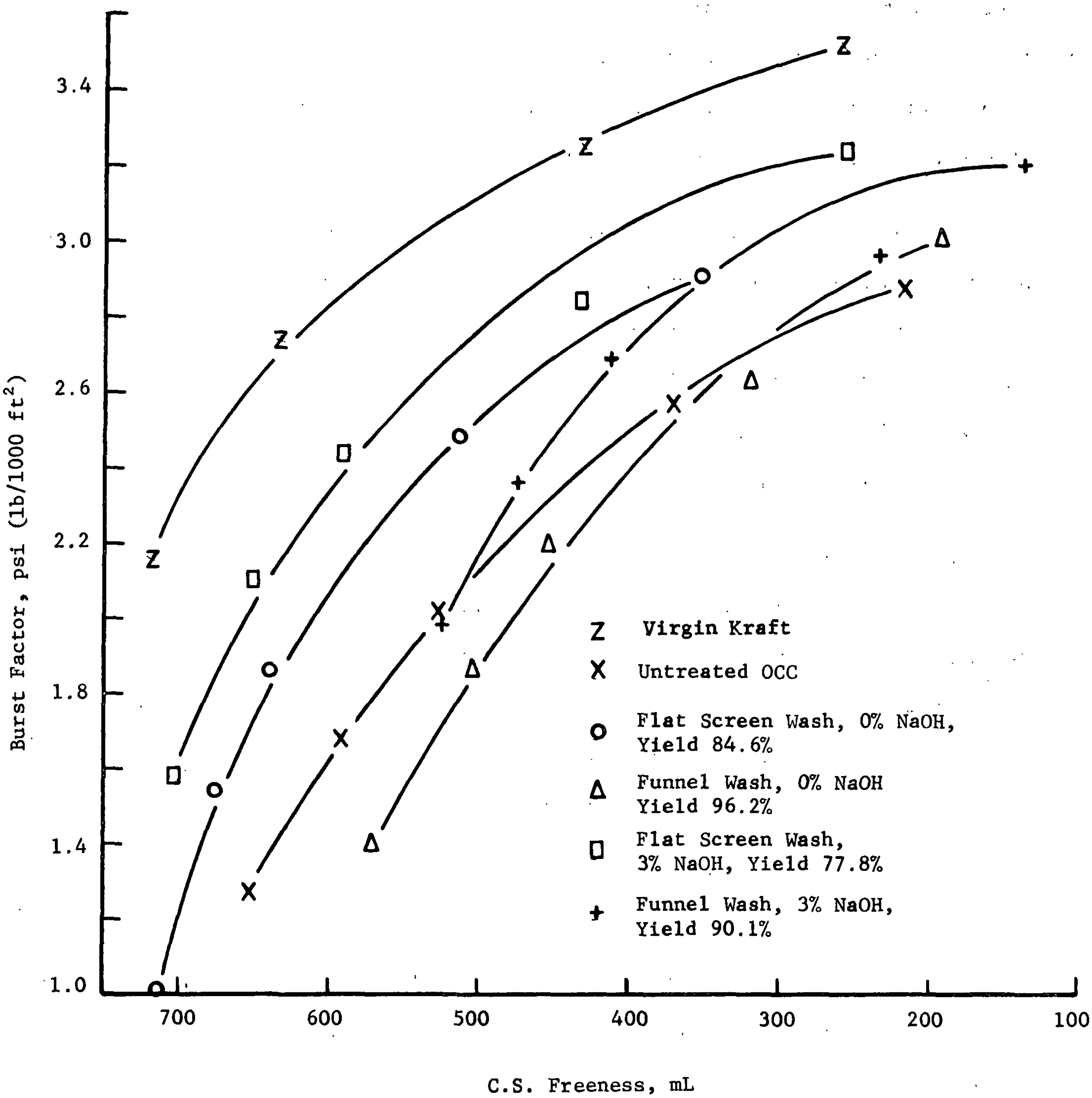

Figure 23. Effect of Caustic Soda Treatments on the Asplund on Burst

than the untreated OCC at 500 mL C.S. freeness (see Table XII). Treatment with caustic soda effected a further improvement in bursting strength of about 10% over the Asplund control. These percentage changes were somewhat less than were obtained with the screen washed green liquor treatment.

At constant freeness the burst results for the untreated OCC and all of the Asplund treatments were below those for virgin kraft. The highest Asplund burst results at constant freeness were achieved with the screen washed caustic soda treatment with fines removed. As in the case of the green liquor trials the removal of fines had a major effect on drainage and burst. The tensile results in Fig. 24 show similar trends.

At constant density Fig. 25 shows that the burst results for the caustic treated screen washed stock were generally slightly lower than for the untreated OCC and other Asplund trials. Thus the removal of fines made it necessary to have a slightly higher density to obtain a given bursting strength for the caustic treated stock with fines removed. A similar effect was obtained in the case of the caustic treated stocks with fines retained.

In the case of tensile strength the funnel washed stocks with fines retained exhibited lower strength than the untreated OCC at constant density (Fig. 26). A similar trend was obtained in the case of the green liquor for the funnel washed stocks. The screen washed Asplund control stocks exhibited about the same tensile strengths as the untreated OCC over most of the density range. The caustic soda treatment resulted in lower tensile strength at a given density or conversely, higher densities at a given tensile strength.

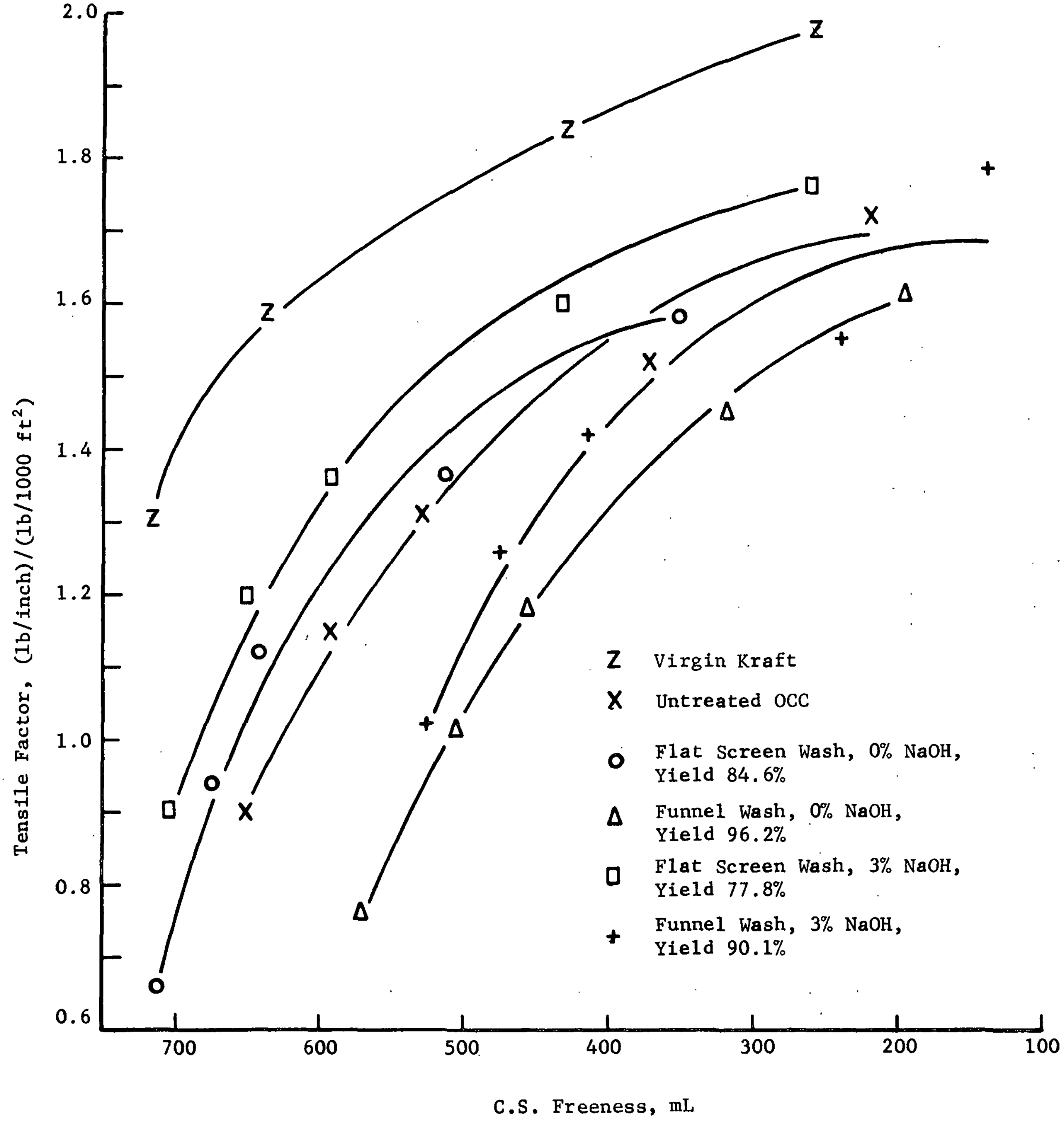

Figure 24. Effect of Caustic Soda Treatments in the Asplund on Tensile

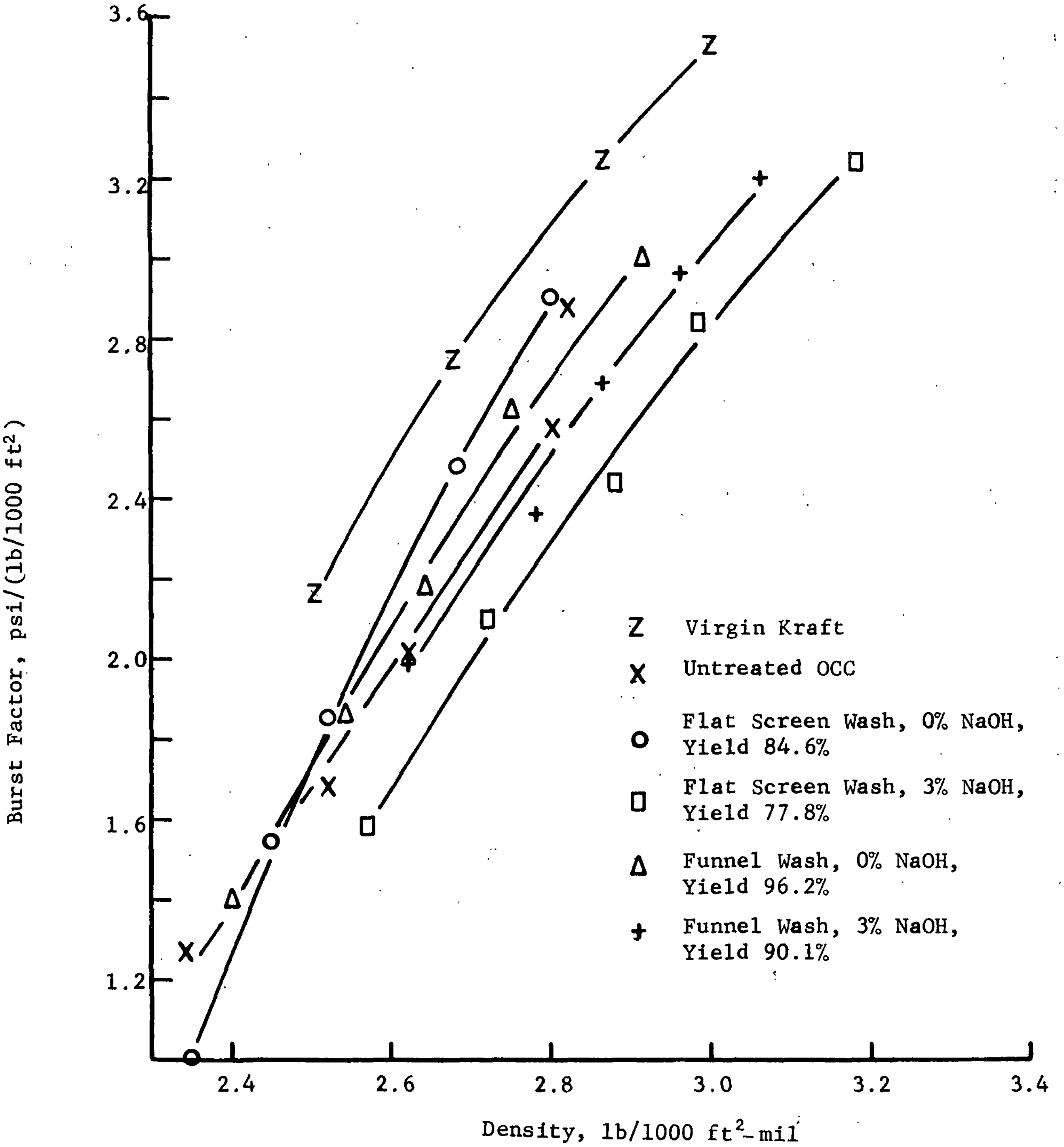

Figure 25. Effect of Caustic Soda Treatments on Burst vs. Density Relationships

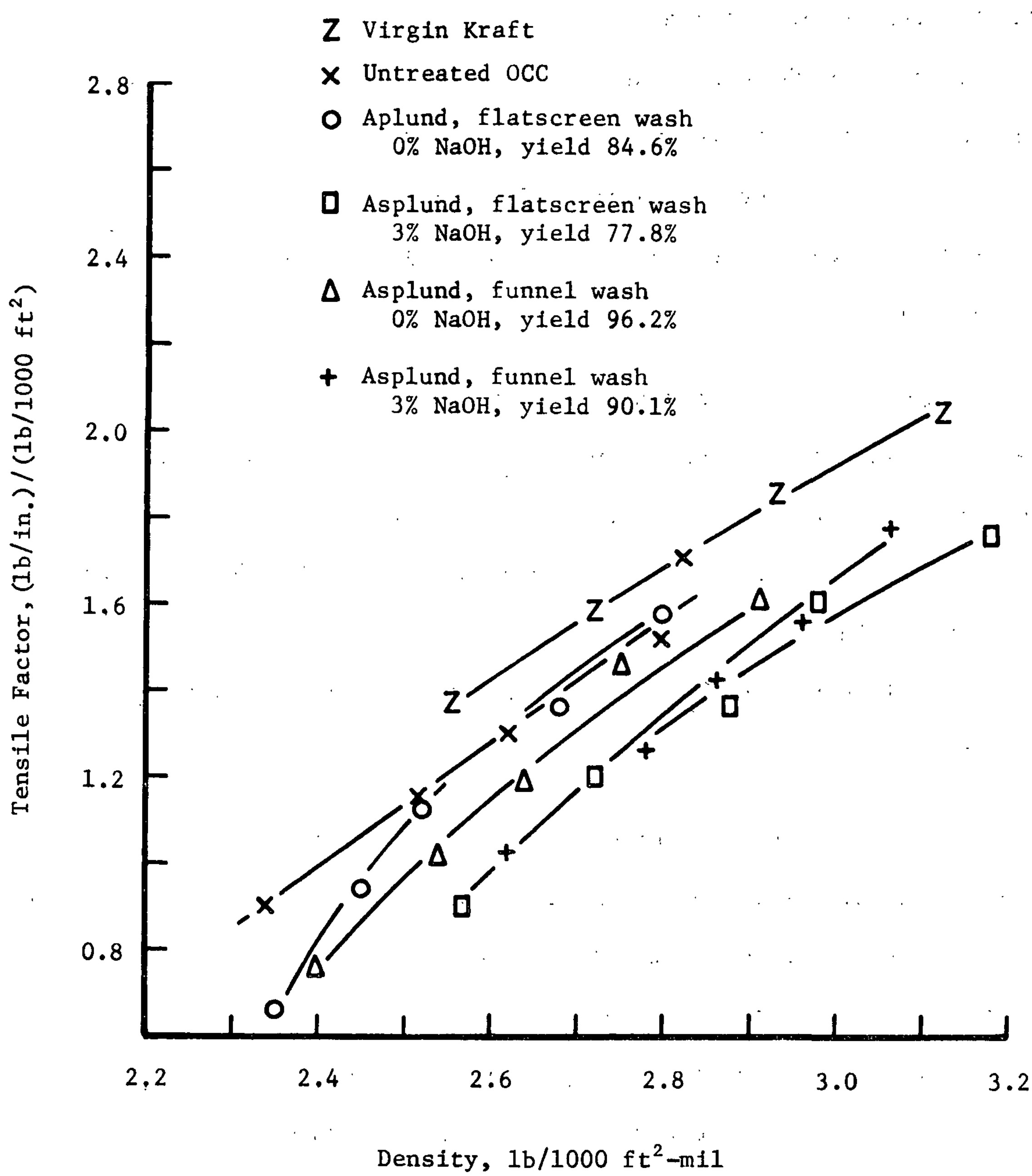

Figure 26. Effect of Caustic Soda Treatments in the Asplund on Tensile vs. Density Relationships

The tear factor vs. freeness results in Fig. 27 show that the funnel washed caustic treated stock exhibited about the same tearing strength as its corresponding Asplund control. Both funnel washed stocks tended to exhibit higher tear than the screen washed Asplund trials and the untreated OCC over most of the freeness range. In the case of the screen washed Asplund trials the caustic treated stock gave tearing strengths which were about the same as its corresponding control and slightly higher than the untreated OCC.

Figure 28 shows that the caustic soda treatments tended to slightly decrease edgewise compression strength relative to the corresponding Asplund controls at constant density. When fines were retained the caustic soda ring compression strengths were slightly lower than obtained in the treatment with fines removed. In general, the results for the untreated OCC and screen washed Asplund control approached the compression results for the virgin stock as density increased.

At a given bursting strength, the caustic soda treated stocks exhibited lower edgewise compression strengths than the untreated OCC and virgin kraft stocks (Fig. 29). They were also lower than the Asplund controls. The untreated OCC, virgin kraft and screen washed Asplund control gave essentially similar burst vs. edgewise compression strength relationships. In general the caustic treatment tended to increase burst at a given compression strength or conversely to lower edgewise compression strength at constant burst.

At a given tearing strength the highest tensile strength results were exhibited by the Asplund caustic soda treatment where the fines were removed (Fig. 30). Somewhat lower tensile strengths at a given tear were obtained using caustic

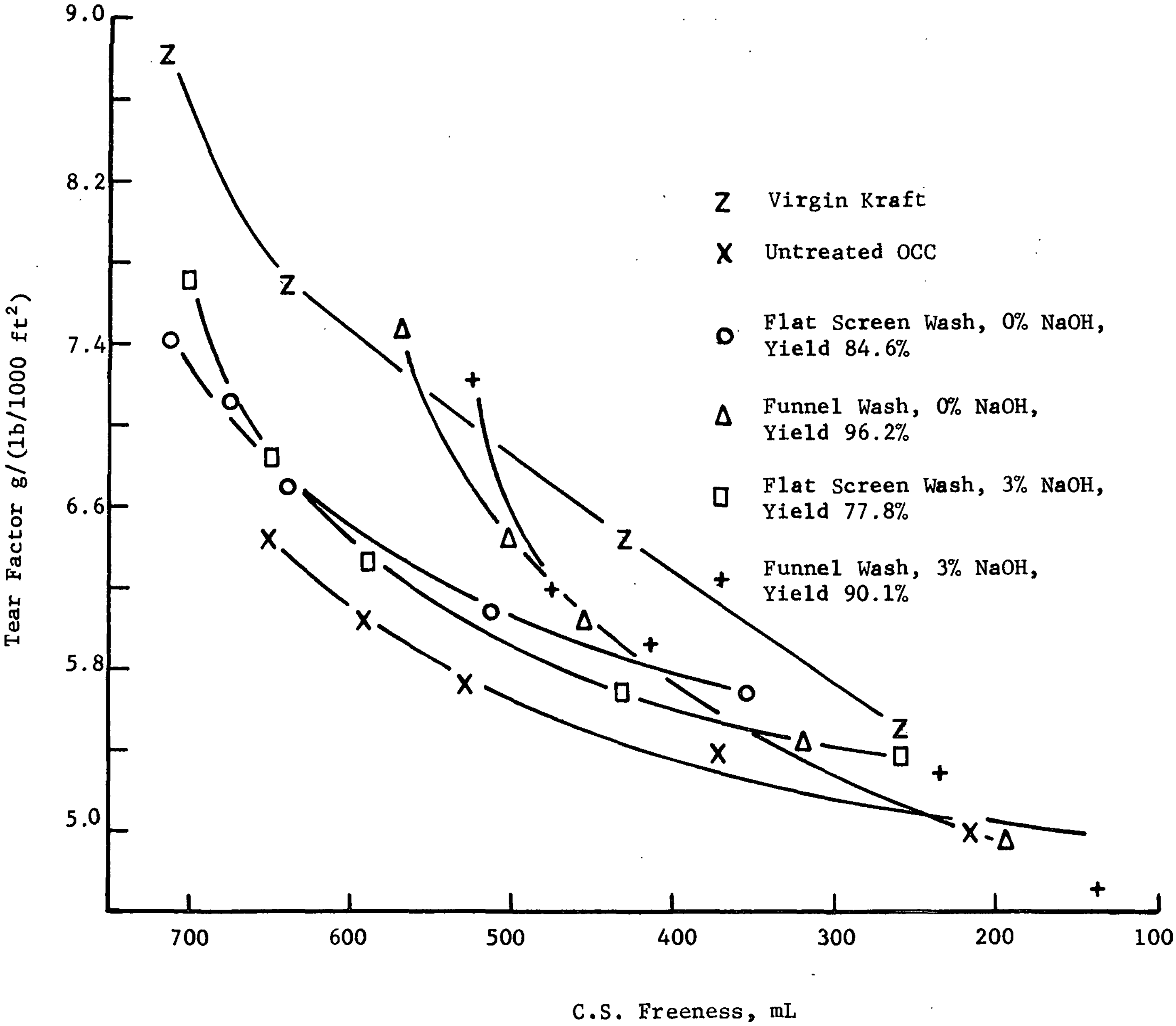

Figure 27. Effect of Caustic Soda Treatments in the Asplund on Tear

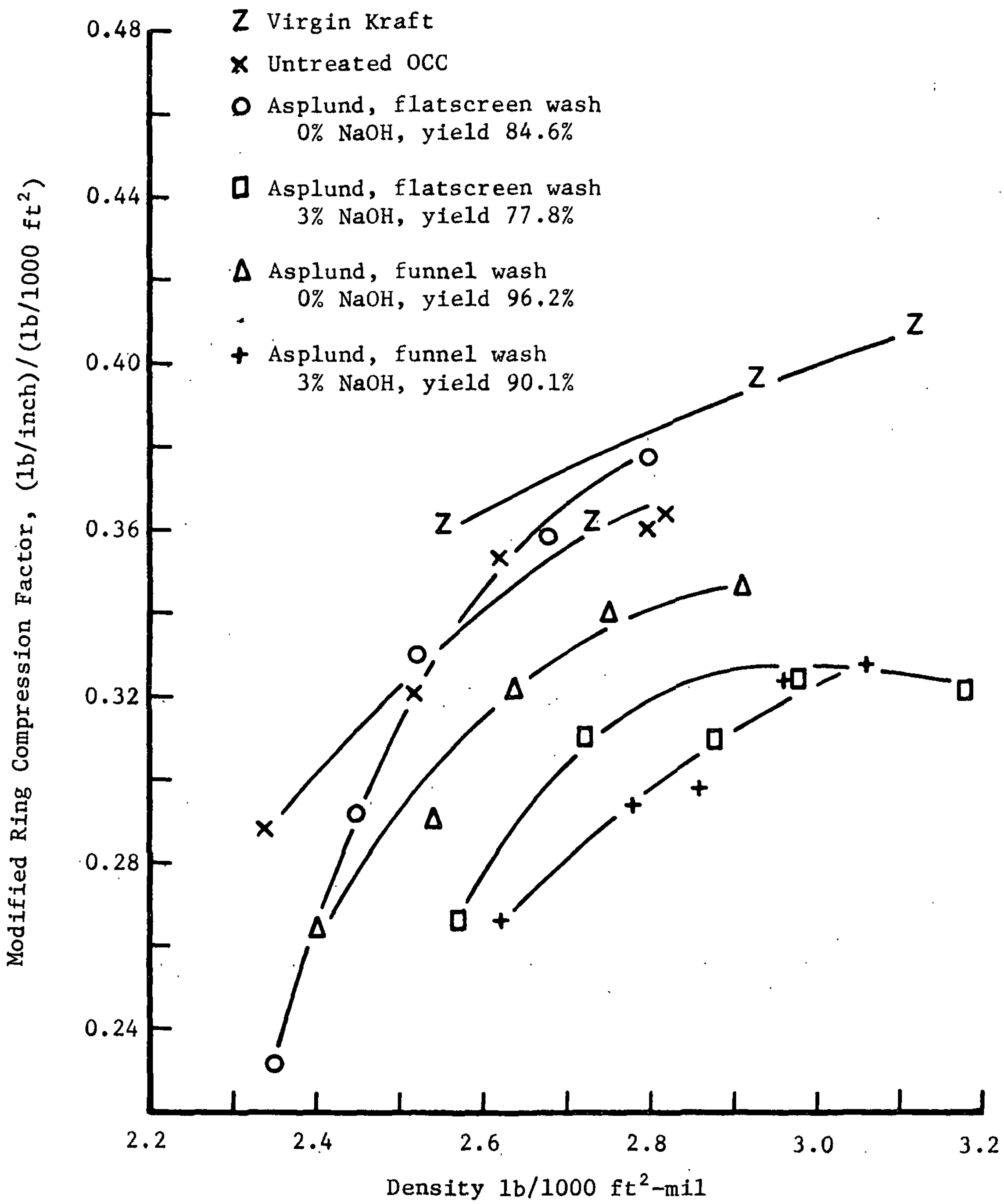

Figure 28. Effect of Caustic Soda Treatments in the Asplund on Edgewise Compression

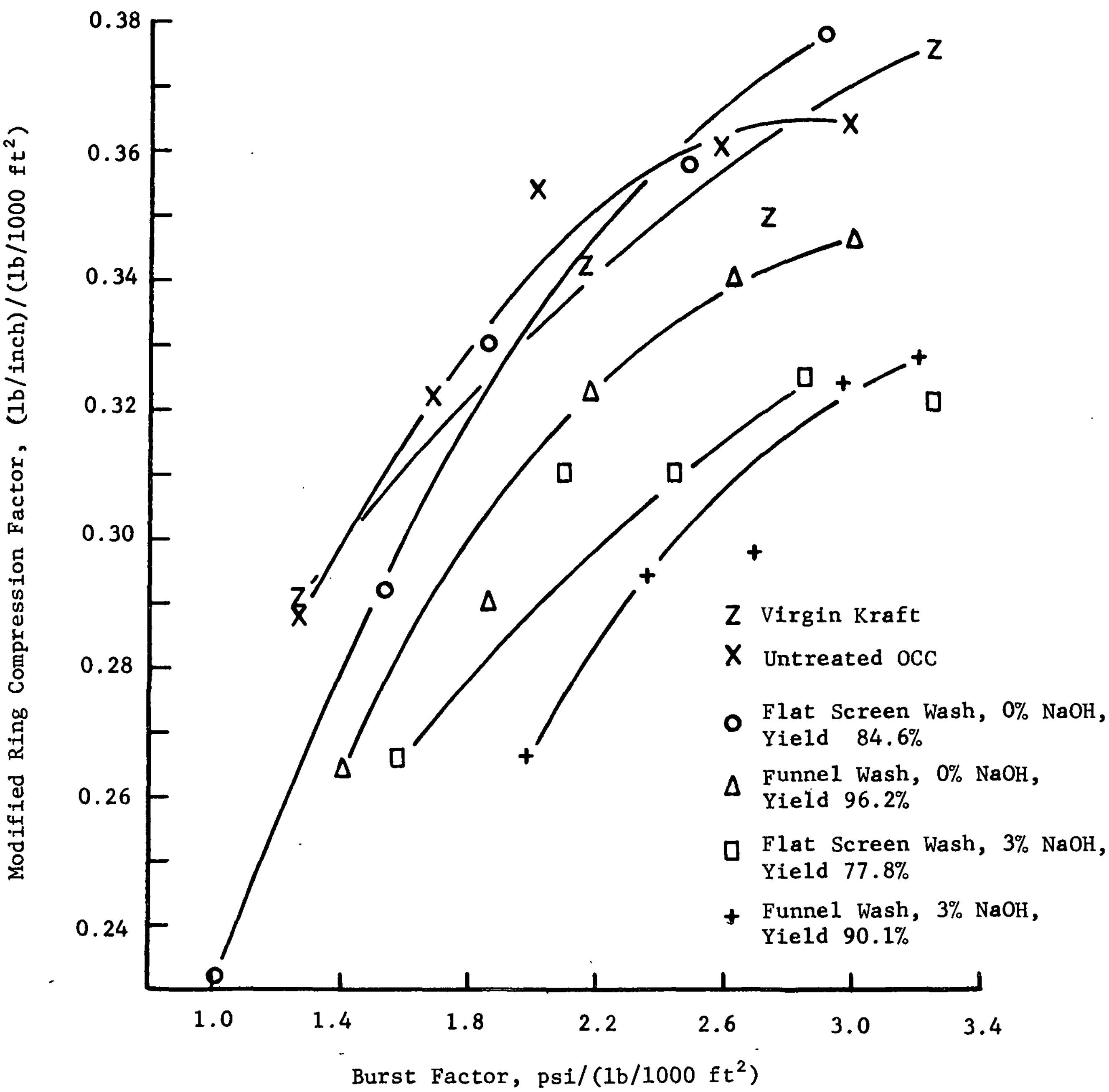

Figure 29. Effect of Caustic Treatments in the Asplund on Burst vs. Modified Ring Compression Relationships

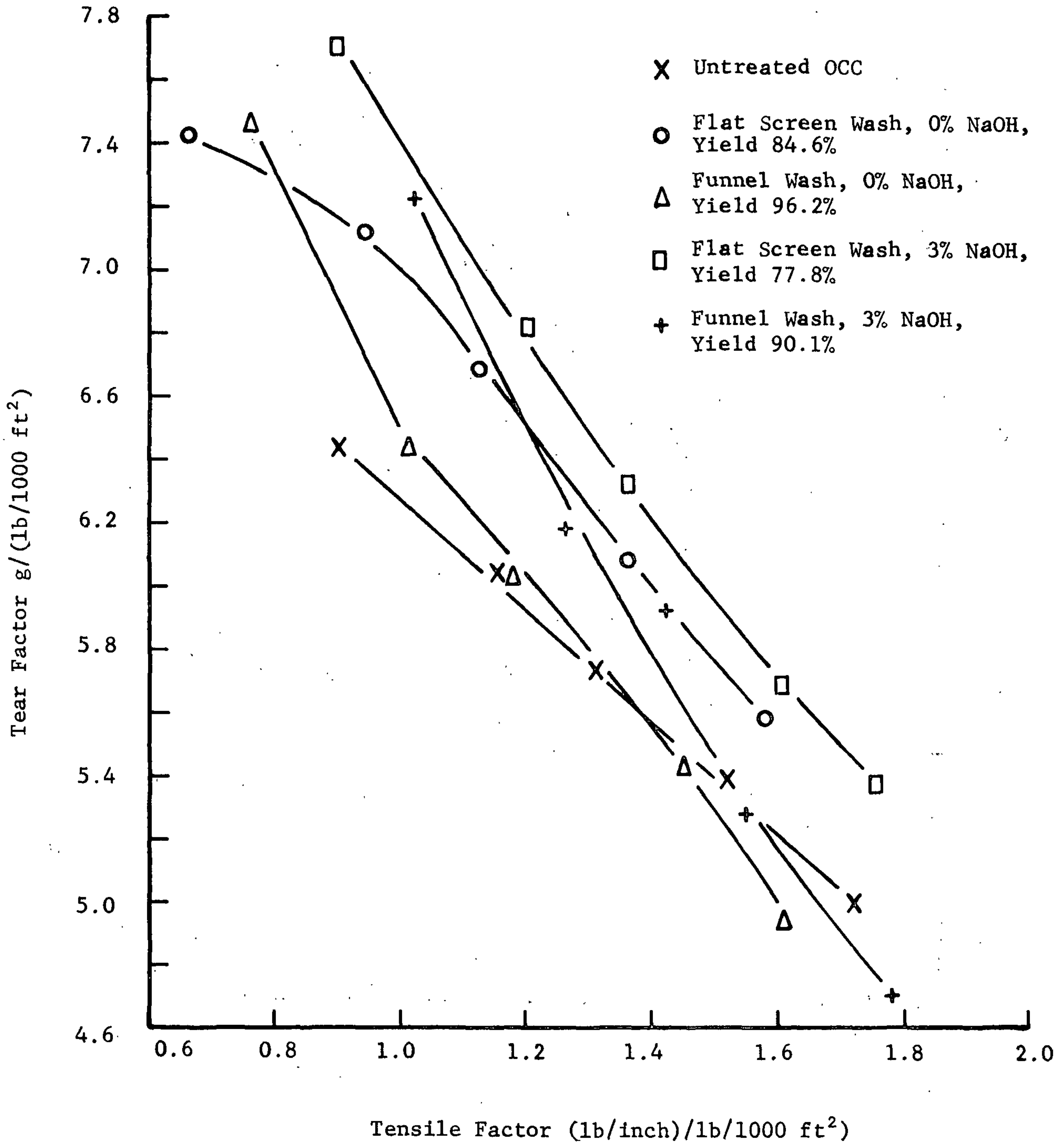

Figure 30. Effect of Caustic Treatments in the Asplund on Tensile vs. Tear Relationships

soda where the fines were retained. In both treatment cases the tensile vs. tear curves lie above those for the untreated OCC over most of the range studied.

As in the case of the green liquor results, all of the Asplund treatments exhibited lower tearing strengths at a given tensile strength than the virgin kraft (see Appendix I).

Briefly summarizing, the caustic soda treatment results indicate the following:

Case 1 Fines retained by means of funnel washing

1. Asplund treatment with no chemical added resulted in large decreases in freeness at a given beating time relative to untreated OCC.

2. Caustic soda treatment in the Asplund decreased freeness relative to both the Asplund control and untreated OCC. In most cases the freeness values after treatment were 100-120 mL below the untreated OCC.

3. At 500 mL C.S. freeness the burst strength after caustic treatment was 16% higher than for the Asplund control but only 1.9% higher than for the untreated OCC. The latter improvement was slightly better than obtained with green liquor.

4. At 500 mL C.S. freeness the caustic treated stock gave tensile strengths which were 17.6% lower than the untreated OCC. A similar trend was obtained in the case of green liquor.

5. The edgewise compression strengths of the caustic treated stocks were lower than obtained with untreated OCC. At 500 mL C.S. freeness the percent reduction in strength was 22.8%. This reduction was considerably greater than obtained with green liquor.

6. At a given bursting strength the caustic soda treated stock exhibited lower edgewise compression strength than the untreated OCC.

Case 2 Fines removed in screen washing process

1. Both the Asplund control and caustic soda treated stocks exhibited higher freenesses at a given beating time than the untreated OCC. In this case caustic soda treatment reduced freeness by about 10-100 mL relative to the Asplund control.

2. At 500 mL freeness the bursting strengths of the Asplund control and caustic treated stocks were 18.8 and 30.0% higher respectively than the result for the untreated OCC.

3. At 500 mL freeness the edgewise compression strength of the Asplund control was 2.0% higher and the caustic treated result was 9.0% lower than obtained with untreated OCC.

4. At constant bursting strength the lowest edgewise compression strengths were obtained for the caustic treated stock with fines retained.

Part 2 — Sodium Carbonate and Other Agents

Prior to carrying out the Asplund treatments described in Part 1, a series of Asplund trials were made using sodium carbonate and hydrogen peroxide. For these trials the following concentrations based on o.d. weight of fiber were applied in the Asplund mill.

Sodium Carbonate: 8 and 13.25%

Hydrogen Peroxide: 2% in alkaline slurry

As mentioned previously, these trials were carried out using a dwell time of 5 min in the Asplund and a steam pressure of 100 psi. A control sample (Asplund control) was processed in the same manner as the chemically treated stocks.

The several charges required for each treatment condition were mixed, washed in a Valley flat screen and collected on a muslin-covered wash box. This procedure resulted in low yields because of the loss of the fine ray cells. For this reason the yields were about the same as shown in Part 1 for the screen washed Asplund trials, i.e., about 80-85%. The fines loss was estimated at about 12%. Because of the fines loss, the effects of the treatment are primarily compared to the Asplund control results in the following discussion.

The beater evaluation results for the sodium carbonate and hydrogen peroxide treatments are tabulated in Table XIV. Comparisons of the effects of the treatments on various properties are shown in Table XV.

In general the 13.25% sodium carbonate treatment produced about the same effects on sheet properties as the 8% level. Therefore, the results obtained

TABLE XIV

EFFECT OF Na_2CO_3 AND H_2O_2 TREATMENTS IN ASPLUND

Treatment	C.S. Freeness	Basis Weight lb/1000 ft^2	Caliper mils	Density, lb/M ft^2-mil	Burst Factor[a]	Tensile Factor[a]
			0 Minute Beating Time			
Untreated	652	13.6	5.8	2.34	1.27	0.90
Asplund control	712	13.2	5.6	2.35	1.01	0.66
8% Na_2CO_3	715	14.0	5.4	2.61	1.29	0.80
13.25% Na_2CO_3	720	13.9	5.5	2.54	1.31	0.83
2% H_2O_2	720	13.4	5.5	2.43	1.09	0.68
			5 Minute Beating Time			
Untreated	592	13.8	5.5	2.52	1.68	1.15
Asplund control	675	13.2	5.4	2.45	1.54	0.94
8% Na_2CO_3	670	13.7	5.1	2.68	1.76	1.09
13.25% Na_2CO_3	675	13.7	5.1	2.69	1.82	1.12
2% H_2O_2	685	13.6	5.3	2.57	1.59	0.92
			10 Minute Beating Time			
Untreated	528	13.6	5.2	2.62	2.01	1.31
Asplund control	640	13.4	5.3	2.52	1.86	1.12
8% Na_2CO_3	620	14.0	5.0	2.78	2.18	1.29
13.25% Na_2CO_3	620	13.7	4.8	2.82	2.24	1.25
2% H_2O_2	640	13.4	5.0	2.67	1.87	1.14
			20 Minute Beating Time			
Untreated	373	13.8	5.0	2.80	2.57	1.52
Asplund control	512	13.6	5.0	2.68	2.48	1.36
8% Na_2CO_3	465	13.9	4.8	2.87	2.70	1.59
13.25% Na_2CO_3	480	13.7	4.8	2.87	2.62	1.50
2% H_2O_2	490	13.4	4.8	2.79	2.56	1.44
			30 Minute Beating Time			
Untreated	218	13.2	4.6	2.82	2.88	1.72
Asplund control	352	13.6	4.8	2.80	2.90	1.58
8% Na_2CO_3	280	13.7	4.5	3.04	3.03	1.76
13.25% Na_2CO_3	315	13.3	4.6	2.92	3.21	1.64
2% H_2O_2	315	13.6	4.7	2.91	3.03	1.76

[a] See end of Table for footnote.

TABLE XIV (continued)

EFFECT OF Na_2CO_3 AND H_2O_2 TREATMENTS IN ASPLUND

Treatment	Tear Factor[a]	Mod. Ring Factor[a]	Et Factor[a]	TEA, $\frac{ft\ lb}{ft^2}$	Stretch, %
		0 Minute Beating Time			
Untreated	6.44	0.288	124.8	1.9	1.82
Asplund control	7.42	0.232	98.0	1.6	2.04
8% Na_2CO_3	8.18	0.246	108.4	2.7	2.63
13.25% Na_2CO_3	7.59	0.287	114.5	2.4	2.34
2% H_2O_2	7.88	0.240	97.8	1.8	2.16
		5 Minute Beating Time			
Untreated	6.04	0.322	144.7	2.8	2.09
Asplund control	7.12	0.292	122.4	2.7	2.44
8% Na_2CO_3	7.72	0.266	131.8	3.9	2.92
13.25% Na_2CO_3	7.15	0.304	139.4	3.3	2.51
2% H_2O_2	6.93	0.286	116.9	2.7	2.40
		10 Minute Beating Time			
Untreated	5.73	0.354	151.8	3.4	2.20
Asplund control	6.69	0.330	135.8	3.3	2.54
8% Na_2CO_3	7.22	0.304	149.1	4.4	2.85
13.25% Na_2CO_3	6.38	0.318	139.3	3.8	2.58
2% H_2O_2	6.52	0.305	137.3	3.4	2.48
		20 Minute Beating Time			
Untreated	5.39	0.361	165.6	4.4	2.49
Asplund control	6.08	0.358	147.6	4.4	2.77
8% Na_2CO_3	6.72	0.332	161.5	5.7	2.97
13.25% Na_2CO_3	6.12	0.339	158.0	5.1	2.87
2% H_2O_2	6.16	0.338	152.6	4.4	2.68
		30 Minute Beating Time			
Untreated	4.99	0.364	179.4	4.8	2.56
Asplund control	5.58	0.378	164.6	5.2	2.86
8% Na_2CO_3	5.49	0.339	179.4	5.9	2.92
13.25% Na_2CO_3	5.37	0.360	175.3	5.4	2.80
2% H_2O_2	5.26	0.356	175.4	5.7	2.85

[a]All factors obtained by dividing the test result, usually in English units, by the basis weight in lb/1000 ft^2.

TABLE XV

COMPARISONS OF STRENGTH PROPERTIES AT CONSTANT FREENESS
ON STOCKS TREATED IN THE ASPLUND DEFIBRATOR
(Screen Washed)

	Untreated OCC	Asplund Control	Asplund Treatments: 2% H_2O_2	Diff., %	3% NaOH	Diff., %	8% Na_2CO_3	Diff., %	13.25% Na_2CO_3	Diff., %
Properties at 600 mL CSF										
Burst factor	1.60	2.07	2.05	-1.0	2.34	+13.0	2.25	+8.7	2.30	+11.1
Mod. ring factor	0.318	0.341	0.314	-7.9	3.07	-10.0	0.307	-10.0	0.321	- 5.9
Tensile factor	1.10	1.22	1.22	0.0	1.32	+ 8.2	1.32	+ 8.2	1.28	+ 4.9
Tear factor	6.08	6.50	6.40	-1.5	6.43	- 1.1	7.15	+10.0	6.35	- 2.3
Properties at 500 mL CSF										
Burst factor	2.13	2.53	2.51	-0.8	2.77	+ 9.5	2.57	+ 1.6	2.57	+ 1.6
Mod. ring factor	0.355	0.362	0.336	-7.2	0.323	-10.8	0.326	- 9.9	0.336	- 7.2
Tensile factor	1.36	1.44	1.42	-1.4	1.56	+ 8.3	1.52	+ 5.6	1.46	+ 1.4
Tear factor	5.63	6.06	6.18	+2.0	5.91	- 2.5	6.82	+12.5	6.14	+ 1.3
Properties at 350 mL CSF										
Burst factor	2.65	2.91	2.92	+0.3	3.14	+ 7.9	2.90	- 0.3	3.09	+ 6.2
Mod. ring factor	0.363	0.379	0.352	-7.1	0.325	-14.2	0.337	-11.1	0.335	-11.6
Tensile factor	1.59	1.58	1.70	+7.6	1.73	+ 9.5	1.69	+ 7.0	1.64	+ 3.8
Tear factor	5.26	5.64	5.43	-3.7	5.50	- 2.5	5.94	+ 5.3	5.50	- 2.5

Note: Differences based on Asplund control as reference. All factors obtained by dividing the test results (usually in English units) by the basis weight in lb/1000 ft^2.

at the lower application level are compared to the peroxide and 3% caustic soda treatment (from Part 1) in the following discussion.

When plotted against freeness the results in Fig. 31 show that the hydrogen peroxide had little effect on bursting strength relative to the Asplund control. The sodium carbonate treatment generally improved bursting strength at a given freeness as compared to the Asplund control. The 3% caustic soda treatment results from Part 1 are also shown in the figure for comparison purposes. The comparison indicates that the caustic soda treatments were slightly more effective in increasing bursting strength at a given freeness than the carbonate or peroxide treatments. The percent changes in bursting strength at 600 and 500 mL C.S. freeness are shown below:

	Percent Change in Burst[a]	
	600 mL Freeness	500 mL Freeness
Caustic soda (3%)	+13.0	+9.5
Sodium carbonate (8%)	+8.7	+1.6
Hydrogen peroxide (2%)	-1.0	-0.8

[a]Relative to Asplund control.

Thus, on a comparative basis the caustic soda and sodium carbonate treatments were more effective than hydrogen peroxide in improving bursting strength.

In Part 1, it was shown that the removal of fines in the washing process substantially increases burst at a given freeness. This effect accounts for the fact that the results for the Asplund control and treatment are higher than the results for the untreated OCC in Fig. 31.

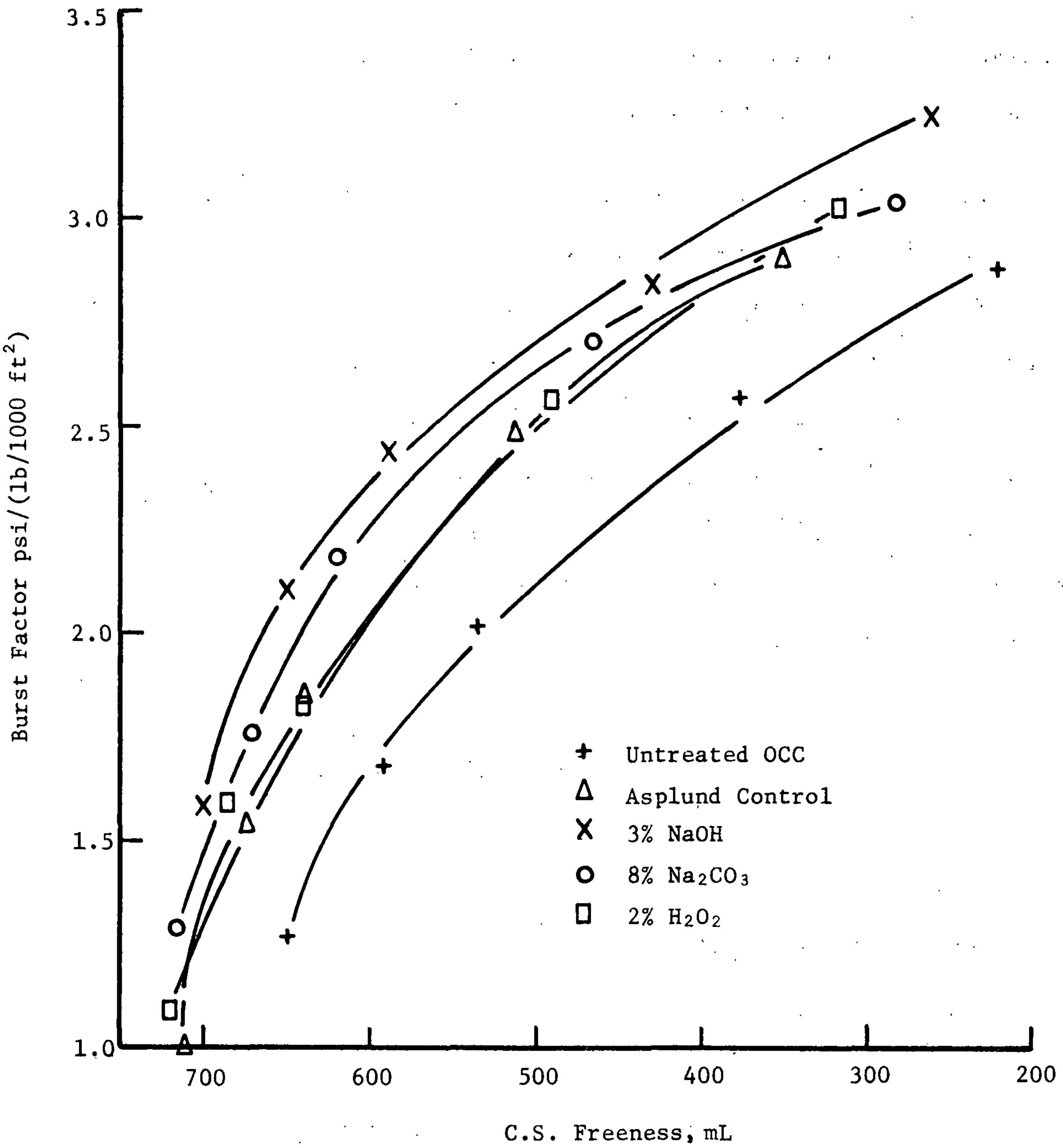

Figure 31. Effect of Various Chemical Treatments in the Asplund on Burst vs. Freeness Relationships

The burst vs. density curves in Fig. 32 show that the chemical treatments generally lowered burst at a given density as compared to the Asplund control and untreated OCC. This effect was generally greatest for the caustic soda and sodium carbonate treatments and reflects some increase in density due to the treatment.

Figure 33 shows that hydrogen peroxide treatment had little or no effect on tensile strength over most of the freeness range. The sodium carbonate and caustic soda treatments slightly increased tensile strength at a given freeness. The improvements in strength at 600 and 500 mL C.S. freeness were about the same as shown below for the caustic soda and sodium carbonate treatments.

	Percent Change in Tensile[a]	
	600 mL freeness	500 mL freeness
Caustic soda (3%)	+8.2	+8.2
Sodium carbonate (8%)	+8.3	+5.6
Hydrogen peroxide	0.0	-1.4

[a]Based on Asplund control.

The edgewise compression strength (modified ring compression) results in Fig. 34 show that the treatments tended to reduce compression strength at a given freeness. This same effect was noted in Part 1 — particularly for the caustic treatment. At 600 and 500 mL C.S. freeness levels the following percent changes were obtained.

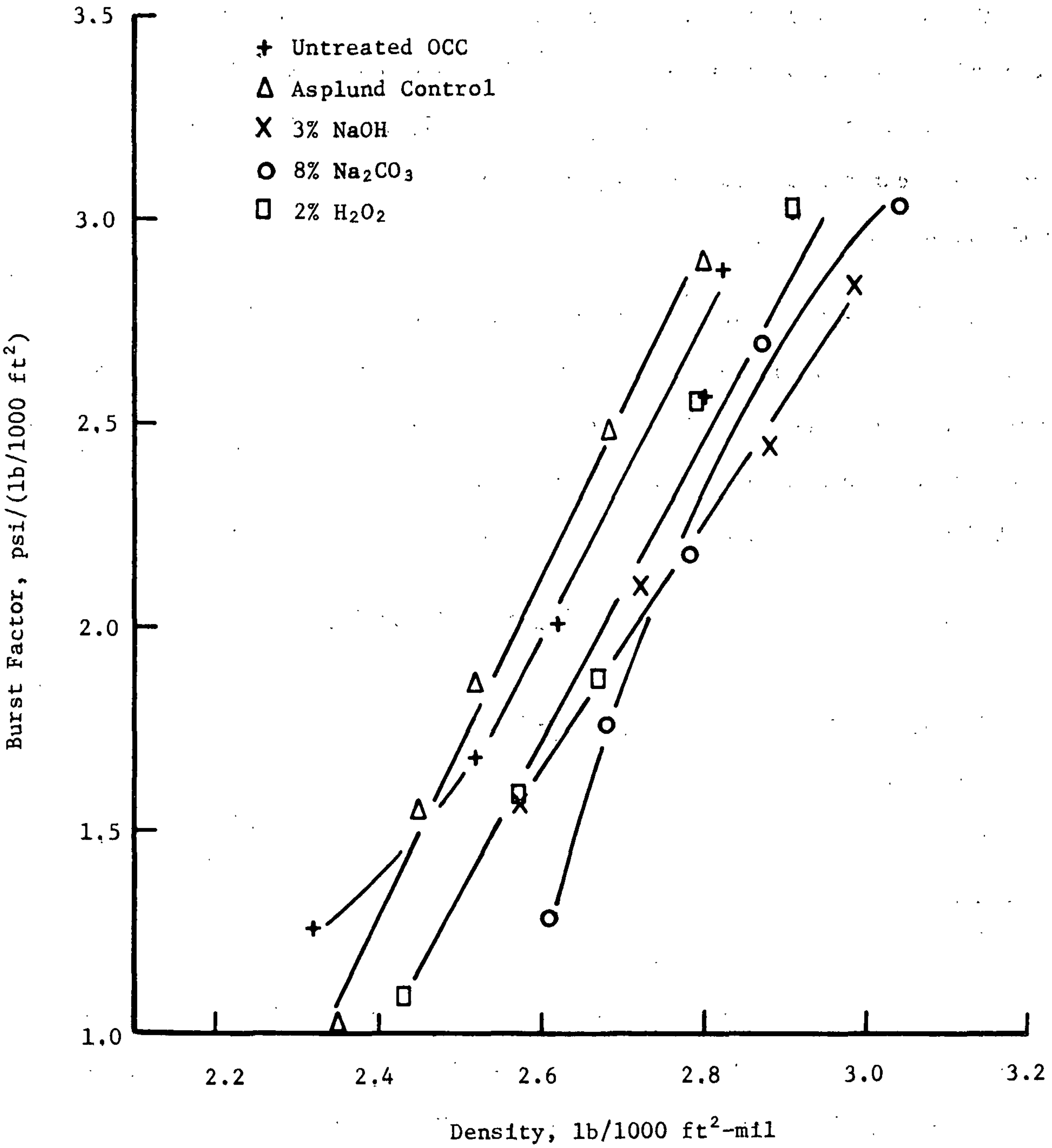

Figure 32. Effect of Various Chemical Treatments in the Asplund on Burst vs. Density Relationships

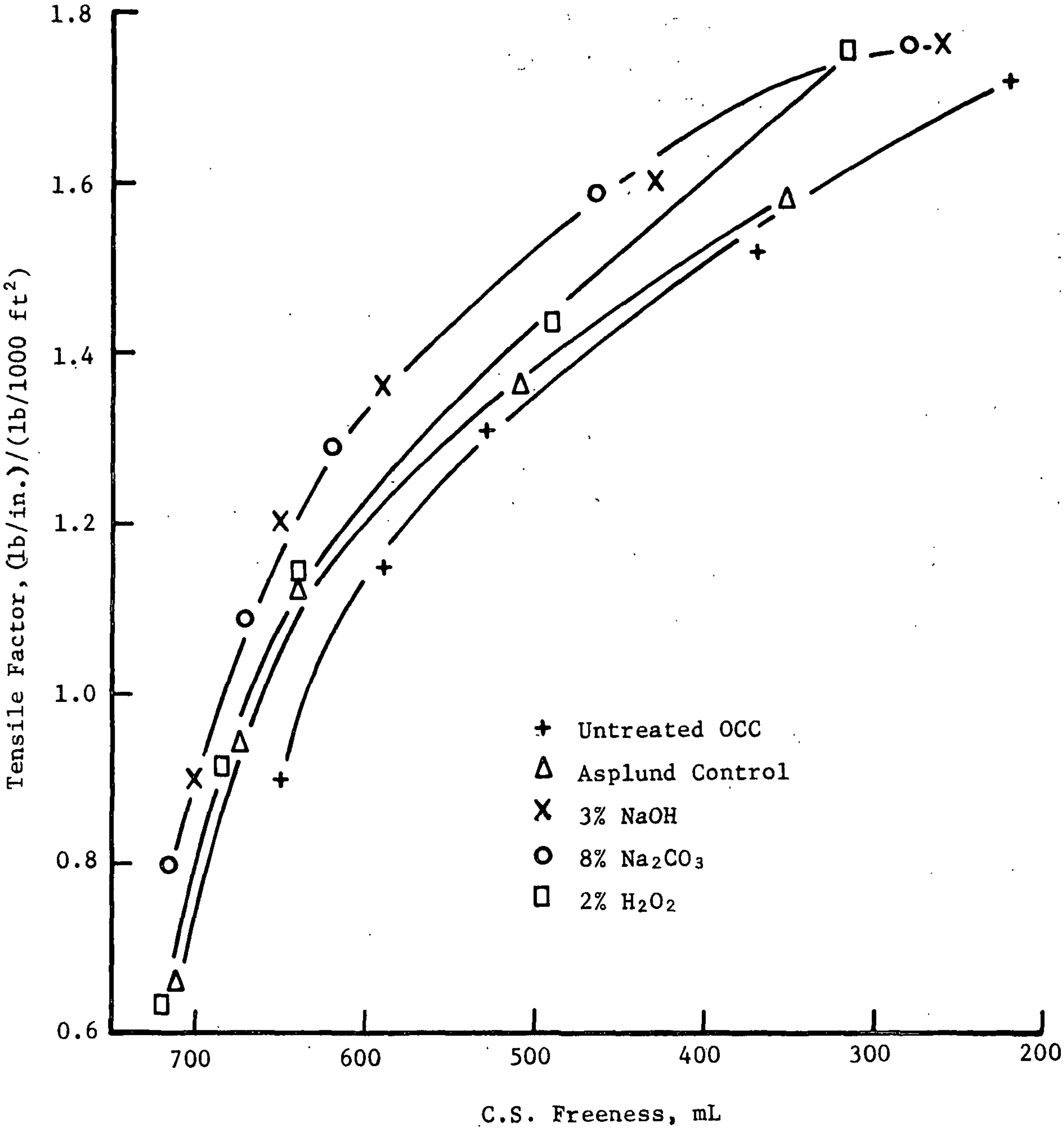

Figure 33. Effect of Various Chemical Treatments in the Asplund on Tensile Strength

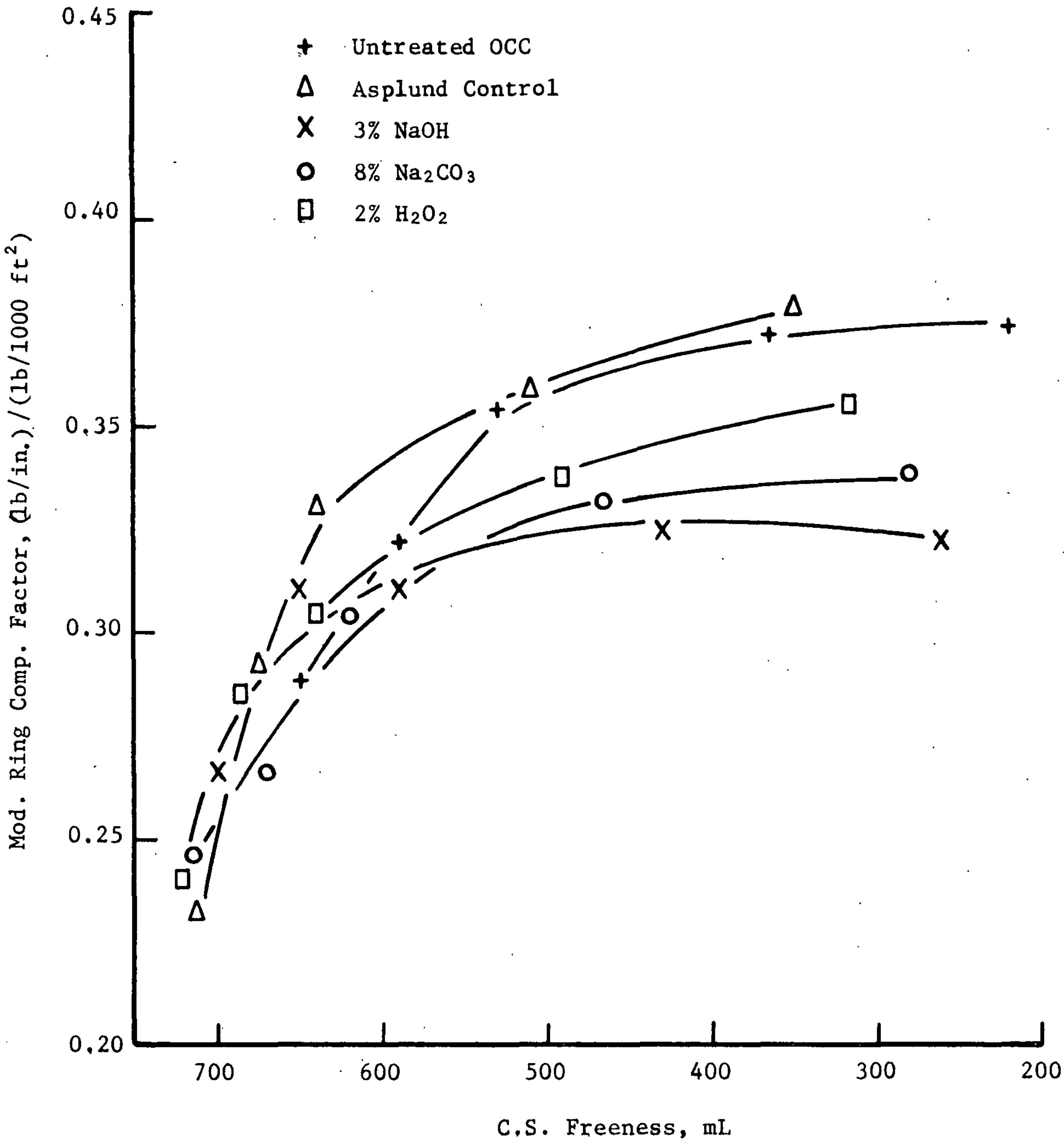

Figure 34. Effect of Various Chemical Treatments in the Asplund on Edgewise Compression Strength

	Percent change in modified ring compression[a]	
	600 mL	500 mL
Caustic soda	-10.0	-10.8
Sodium carbonate	-10.0	-9.9
Hydrogen peroxide	-7.9	-7.2

[a]Based on Asplund control as reference.

Figure 35 shows that the sodium carbonate, caustic soda and hydrogen peroxide treatments tended to reduce edgewise compression strength at a given density. This effort was most pronounced in the case of the sodium carbonate and caustic soda treatments.

The above results indicate that the effects of the caustic soda and sodium carbonate treatments were about the same on edgewise compression strength.

The relationships between burst and modified ring compression are illustrated in Fig. 36. For a given bursting strength, the edgewise compression strengths of the untreated and Asplund control (fines removed) were nearly comparable. The treatments tended to produce modest decreases in edgewise compression strength at a given bursting strength relative to the Asplund control.

In Fig. 37 the results indicate that the Asplund control exhibits higher tearing strength at a given tensile than the untreated OCC. This reflects the removal of fines in processing the Asplund control. The hydrogen peroxide treatment gave about the same tensile — tear relationship as the Asplund control. This would be expected because the peroxide treatment had little effect on either tensile or tearing strength. On the other hand, the caustic soda and carbonate

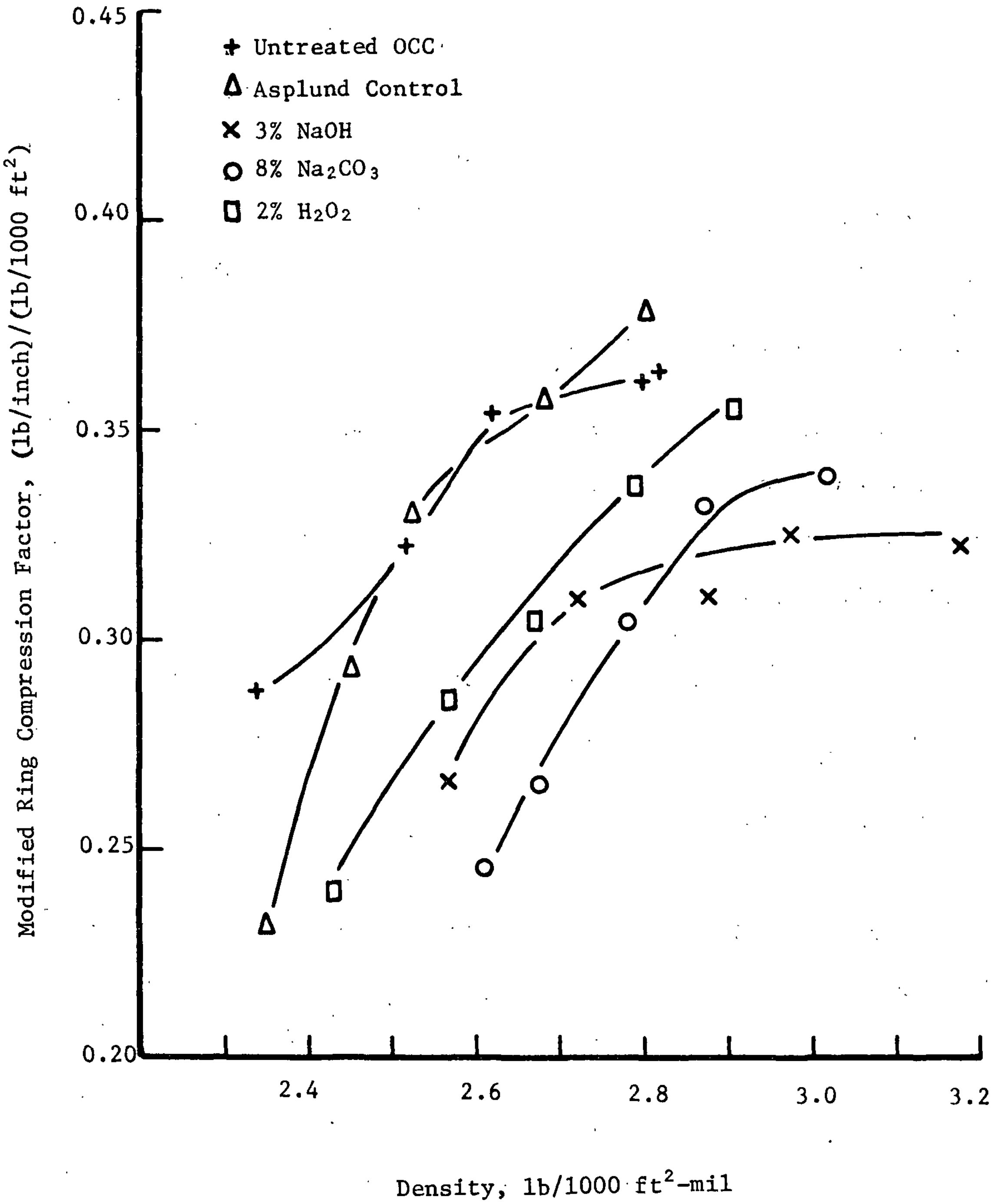

Figure 35. Effect of Chemical Treatments in the Asplund on Edgewise Compression vs. Density Relationships

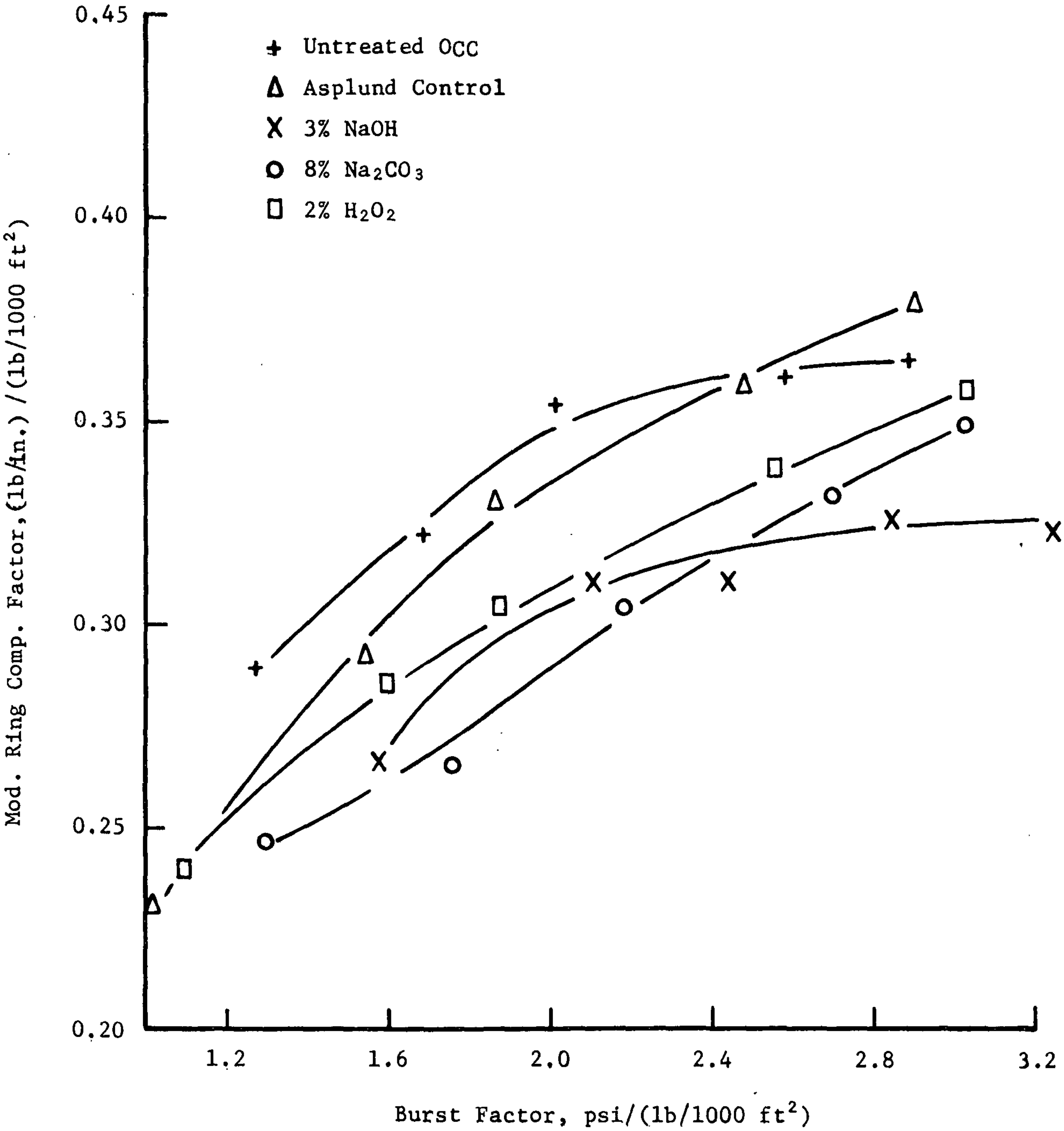

Figure 36. Effect of Various Chemical Treatments in the Asplund on Burst vs. Edgewise Compression Relationships

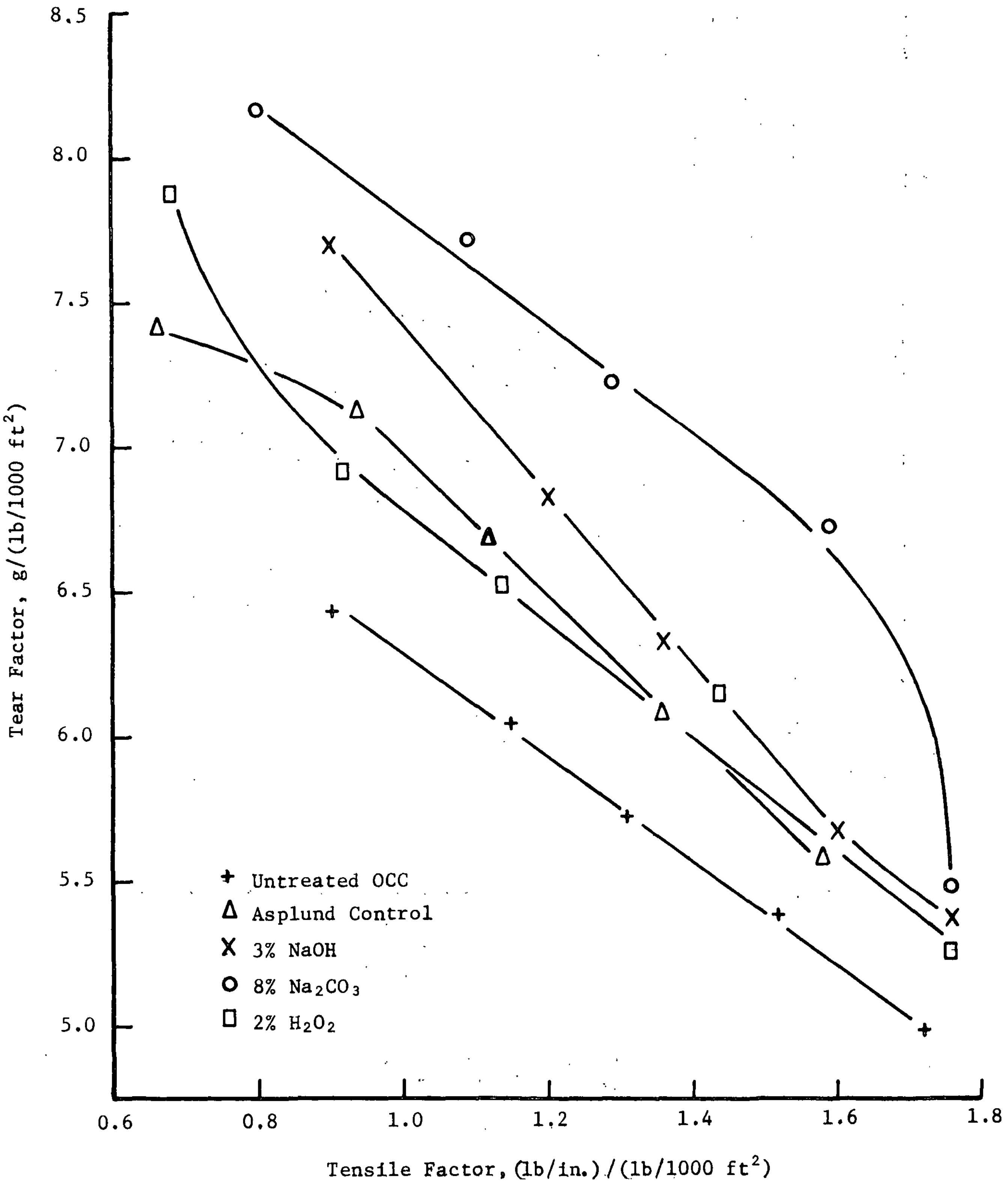

Figure 37. Effect of Various Chemical Treatments in the Asplund on Tensile vs. Tear Relationships

treatments tend to improve tensile strength at a given tearing strength. This reflects the modest increases in bonding and hence tensile strength induced by these treatments.

Briefly summarizing, the sodium carbonate treatment tended to produce small improvements in burst and tensile and some decrease in edgewise compression strengths. In general the effect of an 8% carbonate treatment was about the same as obtained with 3% caustic soda. Hydrogen peroxide at the 2% application level did not have much effect on most properties.

In addition to the above work with sodium carbonate and hydrogen peroxide, Asplund treatments employing white liquor were also carried out for comparison with green liquor. For these trials synthetic liquors were made up having the following chemical amounts per 500 mL water.

	White Liquor	Green Liquor
Sodium hydroxide	46.9	--
Sodium carbonate	15.0	77.1
Sodium sulfide	15.7	15.7

The trials were carried out using the less severe Asplund conditions used in the green liquor trials in Part 1. Thus, the dwell time was 2.5 min in the Asplund mill and the steam pressure was 50 psi. A control sample (Asplund control) was processed in the same manner as the chemically treated stocks.

The treated stocks were washed on a Valley flat screen and collected on a wash box. Thus, fines were lost and the yields were about the same as shown in Part 1 for the screen washed Asplund trials. Because of the fines loss the effects of the treatments are primarily compared to the Asplund control results as in the preceding section.

The beater evaluation results for the white liquor trials are shown in Table XVI. Also tabulated are the green liquor results from Part 1. Comparisons of the effects of the treatments on various properties are shown in Table XVII.

At constant freeness the results in Table XVII suggest that the 3% white liquor treatment did not have much effect on the burst, tensile, tear and edgewise compression strength of the stock. The changes in properties were generally less than obtained with the green liquor. This result was somewhat unexpected in view of the caustic soda results obtained in Part 1. Additional trials would be needed to determine the reasons for the lesser changes.

CHARACTERIZATION OF FURNISHES

In the initial phases of the study beater evaluations were carried out on the following:

1. virgin primary stock
2. composite (combined) OCC
3. liner fraction of OCC
4. medium fraction of OCC

The liner and medium fractions were obtained by wetting the combined board (OCC) and hand-separating the liners from the medium. The sheets were made to a weight of 42 lb/1000 ft^2 and drum dried.

It should be kept in mind that the linerboard used in making the combined board OCC sample came from a different source than the virgin primary pulp.

TABLE XVI

EFFECT OF TREATMENTS WITH "WHITE LIQUOR" IN THE ASPLUND DEFIBRATOR
(Screen Washed)

Treatment	C.S. Freeness, mL	Basis Weight, lb/1000 ft^2	Caliper, mil	Density, lb/1000 ft^2-mil	Burst Factor	Tensile Factor	Tear Factor	Mod. Ring Factor	Et Factor	TEA, ft lb/ft^2	Stretch, %	Concora, psi[a]
0 Minute Beating Time												
Untreated OCC	652	13.6	5.8	2.34	1.27	0.90	6.44	0.288	124.8	1.9	1.82	14.8
Asplund control	730	14.2	6.2	2.30	0.96	0.68	6.91	0.156	105.6	1.6	1.84	9.5
3% white liq.	725	13.8	5.4	2.57	1.50	0.95	6.87	0.192	126.9	3.0	2.52	19.0
5% white liq.	720	13.3	5.3	2.53	1.51	0.91	7.79	0.229	123.2	2.9	2.59	18.5
3% green liq.	730	14.0	5.6	2.48	1.44	0.90	7.70	0.225	120.1	2.7	2.43	15.3
5 Minute Beating Time												
Untreated OCC	592	13.8	5.5	2.52	1.68	1.15	6.04	0.322	144.7	2.8	2.09	20.5
Asplund control	700	14.2	5.8	2.43	1.50	0.98	7.50	0.215	131.8	2.7	2.21	14.8
3% white liq.	690	13.9	5.2	2.68	1.99	1.17	6.74	0.238	146.7	3.6	2.55	25.2
5% white liq.	665	13.8	5.1	2.70	2.01	1.17	6.26	0.253	142.8	3.9	2.73	25.9
3% green liq.	690	14.3	5.4	2.67	1.93	1.13	7.22	0.245	142.3	3.5	2.52	20.9
10 Minute Beating Time												
Untreated OCC	528	13.6	5.2	2.62	2.01	1.31	5.73	0.354	151.8	3.4	2.20	26.0
Asplund control	670	14.2	5.6	2.53	1.98	1.14	7.06	0.258	131.9	3.2	2.31	20.8
3% white liq.	630	13.9	5.1	2.75	2.29	1.38	6.57	0.270	153.2	4.3	2.67	30.2
5% white liq.	610	13.3	4.9	2.72	2.30	1.37	5.88	0.262	154.9	4.2	2.71	29.8
3% green liq.	650	14.2	5.2	2.74	2.25	1.31	6.47	0.274	149.8	3.9	2.49	26.9
20 Minute Beating Time												
Untreated OCC	372	13.8	5.0	2.80	2.57	1.52	5.39	0.361	165.6	4.4	2.49	32.0
Asplund control	550	14.2	5.3	2.67	2.52	1.42	6.02	0.267	156.2	4.3	2.52	29.5
3% white liq.	430	13.7	4.9	2.82	2.88	1.63	5.62	0.273	176.6	5.1	2.71	37.2
5% white liq.	435	13.8	4.8	2.91	2.88	1.63	5.23	0.296	175.8	5.5	2.82	40.2
3% green liq.	510	14.4	5.1	2.84	2.79	1.58	5.98	0.292	171.1	5.1	2.64	34.7
30 Minute Beating Time												
Untreated OCC	218	13.2	4.6	2.82	2.88	1.72	4.22	0.364	179.4	4.8	2.56	33.8
Asplund control	405	14.3	5.1	2.78	2.89	1.65	5.68	0.315	176.0	5.1	2.59	35.4
3% white liq.	280	13.7	4.7	2.94	3.30	1.84	5.01	0.291	192.7	5.7	2.75	40.1
5% white liq.	255	13.8	4.7	2.92	3.29	1.80	4.69	0.260	190.6	6.0	2.86	40.1
3% green liq.	360	14.1	4.8	2.92	3.20	1.73	5.50	0.309	183.8	5.5	2.72	38.3

Note: All factors obtained by dividing the test value usually in English units, by the basis weight in lb/1000 ft^2.

[a] On 26 lb/1000 ft^2 sheets.

TABLE XVII

EFFECT OF GREEN AND WHITE LIQUOR TREATMENTS AT CONSTANT FREENESS
(Referenced to Asplund Control)

Asplund Treatments at 50 psi

	Untreated OCC	Asplund Control	3% White Liquor	Diff., %[a]	3% Green Liquor	Diff., %[a]
Properties at 600 cc CSF						
Burst factor	1.60	2.38	2.38	0.0	2.53	+6.3
Mod. ring factor	0.318	0.271	0.270	-0.4	0.280	+3.3
Tensile factor	1.10	1.31	1.42	+8.4	1.42	+8.4
Tear factor	6.08	6.33	6.42	+1.4	6.44	+1.7
Properties at 500 cc CSF						
Burst factor	2.13	2.73	2.67	-2.2	2.94	+7.7
Mod. ring factor	0.355	0.293	0.272	-7.2	0.292	-0.3
Tensile factor	1.36	1.50	1.54	+2.7	1.58	+5.3
Tear factor	5.63	5.82	5.88	-1.0	5.87	+0.9
Properties at 350 cc CSF						
Burst factor	2.65	--[b]	--[b]	--[b]	3.21	--[b]
Mod. ring factor	0.363	--	--	--	0.310	--
Tensile factor	1.59	--	--	--	1.74	--
Tear factor	5.26	--	--	--	5.48	--

[a] Differences are based on Asplund control as reference.

[b] Freeness after 30 min beating above 350 mL.

Note: Factors obtained by dividing the test value, usually in English units, by the basis weight in lb/1000 ft^2.

Nevertheless the following comparisons provide some insight into the relative strengths of the several furnishes.

The results in Fig. 38 indicate that the liner fraction has good strength potentials in terms of bursting strength. At the same freeness the liner fraction bursting strength is somewhat lower than that of the virgin kraft. This may be attributed to the previous papermaking and repulping effects experienced by the liner fraction as well as to the fact the two furnishes came from different manufacturers. On the other hand the hardwood medium fraction has low freeness and bursting strength. The bursting strength of the composite OCC is lower than that of the liner fraction and reflects the fact it is a mixture of the softwood kraft and hardwood semichemical fibers.

At a given density the liner fraction and composite OCC have about the same bursting strength (Fig. 39). However, their strength is somewhat lower than that of the virgin OCC and considerably higher than that of the medium fraction. Thus, it appears that the bursting strength of repulped OCC is primarily related to the characteristics of the liner fraction. It may be speculated that when the composite OCC is refined, more of the refining energy is applied to the long softwood fibers and less work is done on the hardwood fiber.

Because of the differences in fiber species and degree of delignification the softwood and hardwood fractions can be expected to respond differently to mechanical and chemical treatments. Therefore, fractionation followed by separate treatment of either or both fractions needs further research.

The above effects show up on other properties although in different ways. For example the edgewise compression strengths of the stocks are plotted vs.

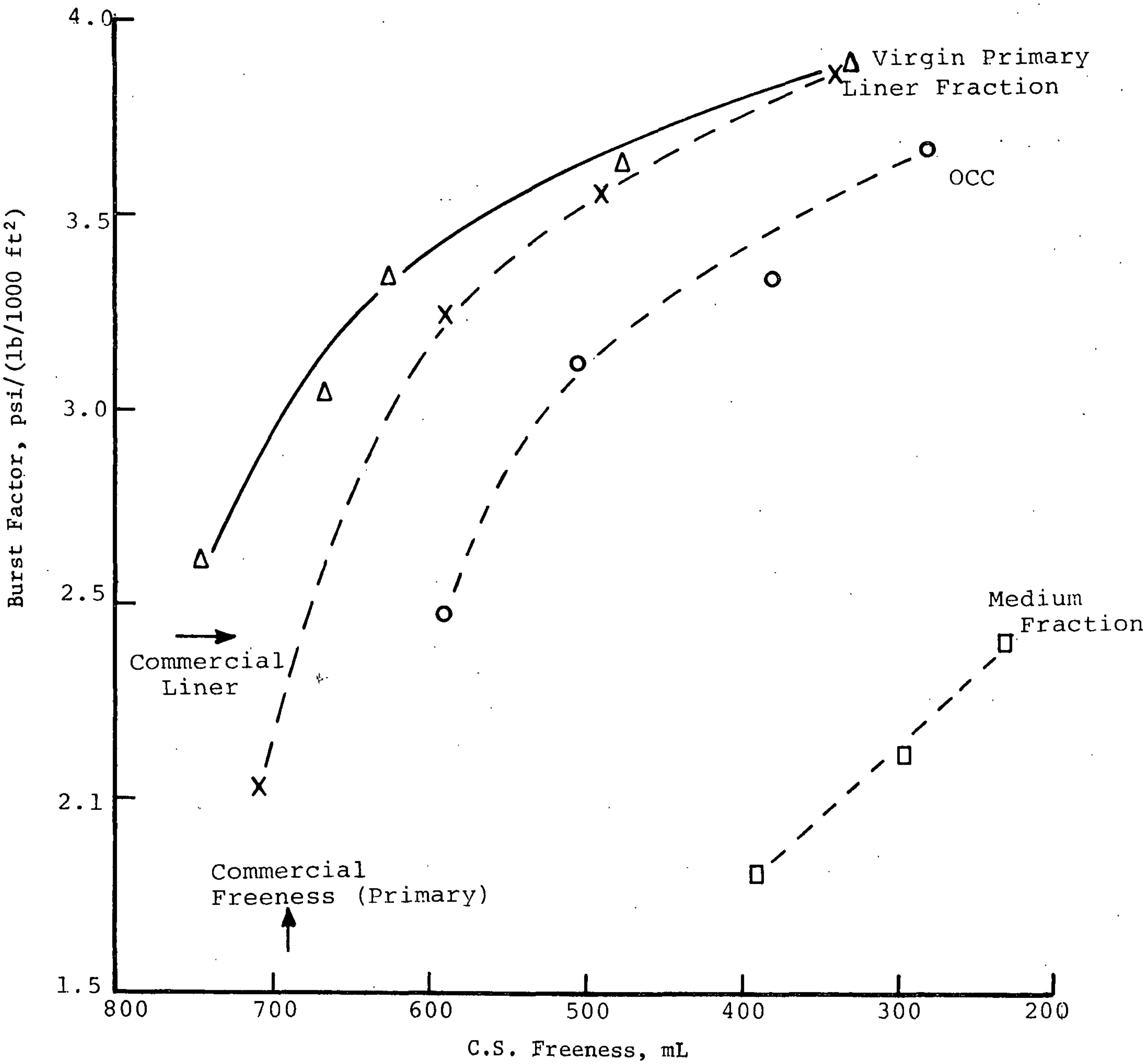

Figure 38. Burst vs. Freeness for OCC and Virgin Kraft

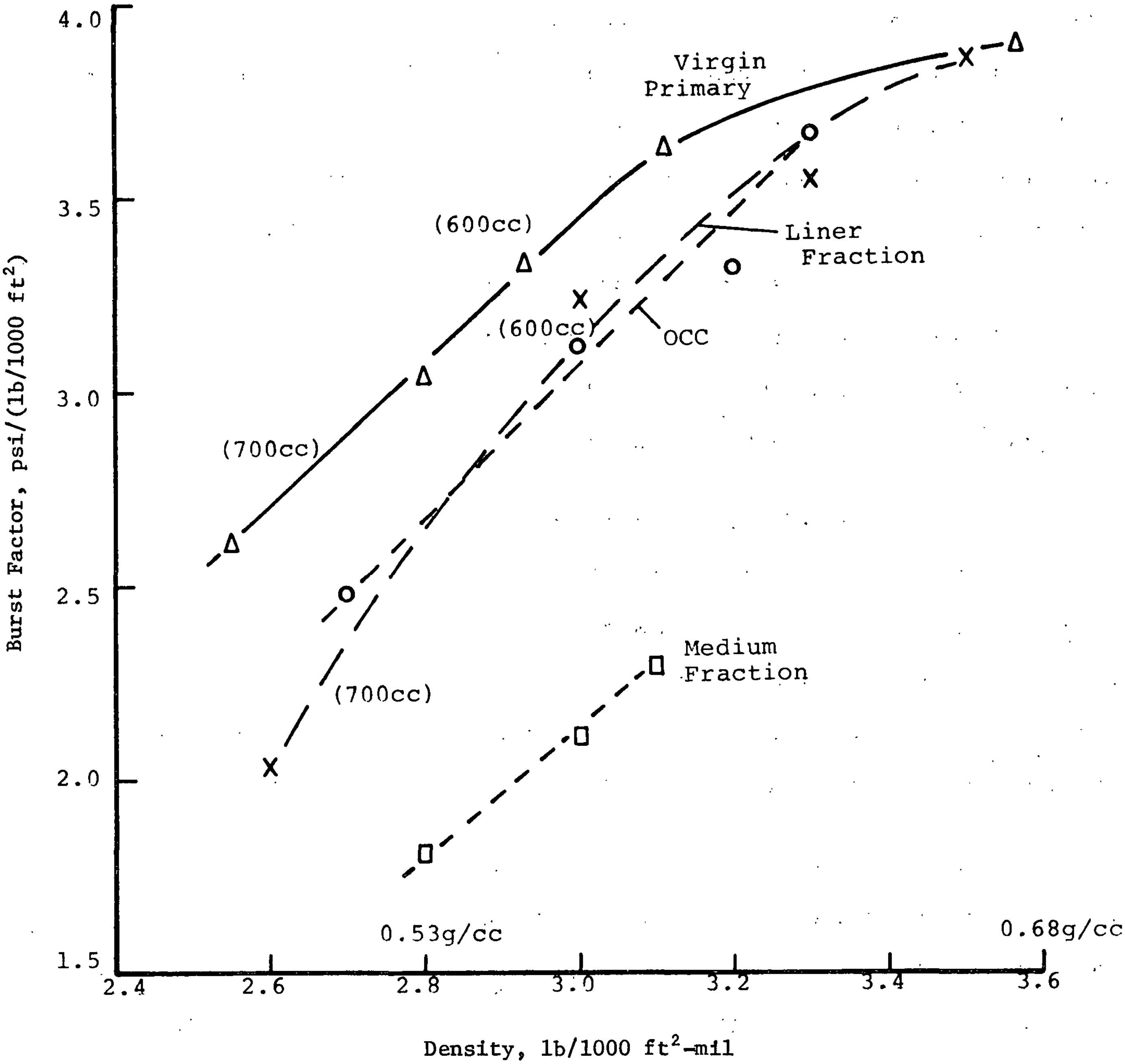

Figure 39. Burst vs. Density for OCC and Virgin Kraft

freeness and density in Fig. 40 and 41 respectively. Figure 40 indicates that the liner fraction and virgin kraft have essentially comparable compression strengths at a given freeness. The medium fraction has relatively high compression strength but it is achieved at low freeness levels. At constant density Fig. 41 indicates that the edgewise compression strength of the medium fraction is greater than the compression strength of the virgin kraft, the liner fraction and the composite OCC. This may be attributed to the short stiff nature of the hardwood fibers. However, it appears that the beneficial compression aspects of the hardwood fibers are not fully utilized in the composite OCC. This suggests there may be a potential for better utilization of OCC through separate treatment of the fractions.

The burst vs. edgewise strength results in Fig. 42 show that the curve for the composite OCC is close to that of the virgin primary although achieved at lower freeness levels. Both the composite OCC and virgin kraft stocks exhibit lower compression strengths than the repulped liner fraction at a given bursting strength. The results also appear to indicate that the high compression strength of the medium fraction is not fully utilized in the composite OCC blend.

Most of the other properties of OCC also reflect in varying ways the heterogeneity of the furnish. As a final example the Z-direction tensile results are shown in Fig. 43 as a function of density. Z-direction tensile is often taken as a measure of bonding strength. It may be observed that the liner fraction and virgin primary stocks follow essentially the same relationship. At a given density they have a lower Z-direction tensile strength than the medium fraction. The medium fraction, of course, is at a much lower freeness level. The composite

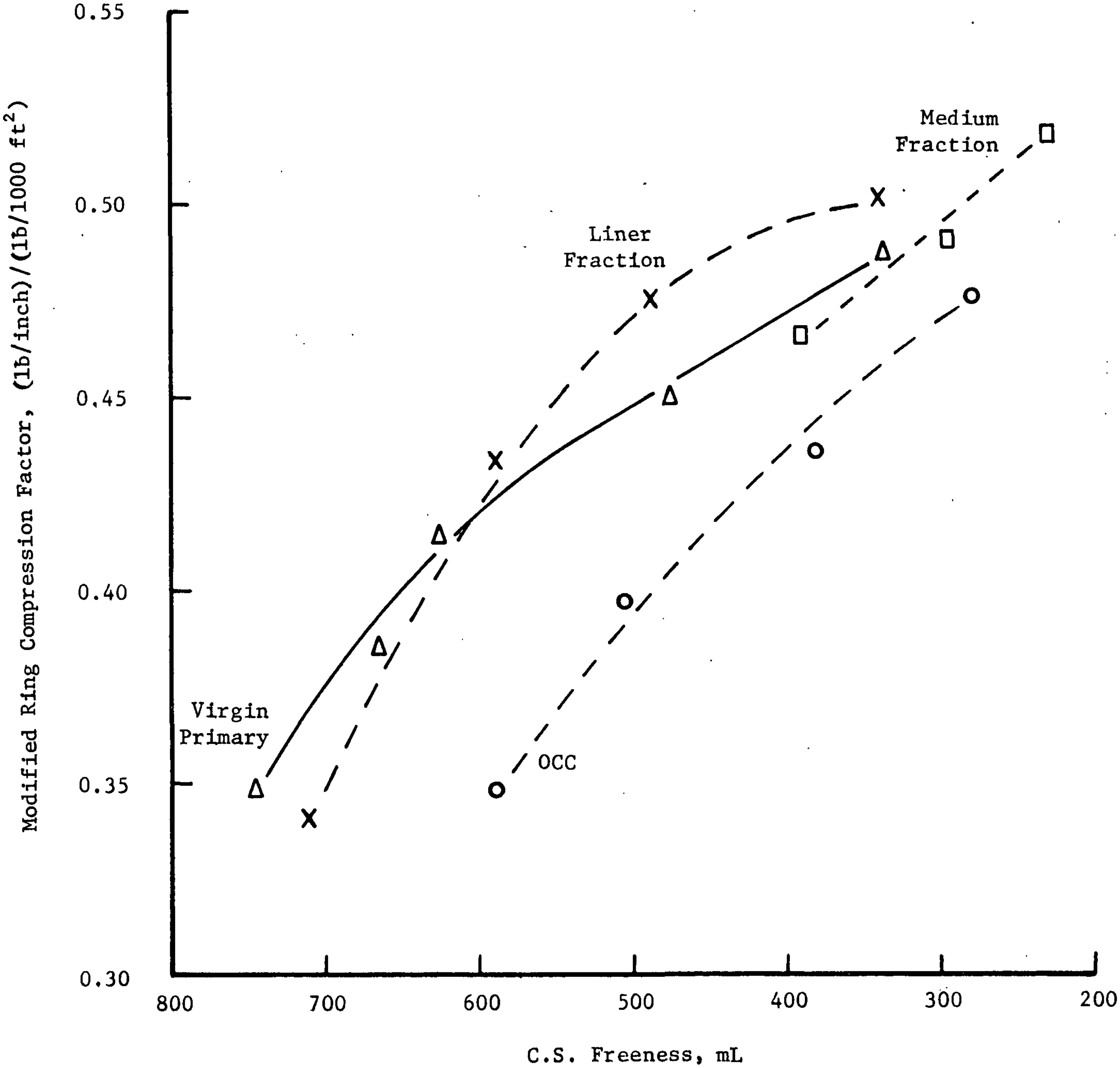

Figure 40. Edgewise Compression Strength vs. Freeness for OCC and Virgin Kraft

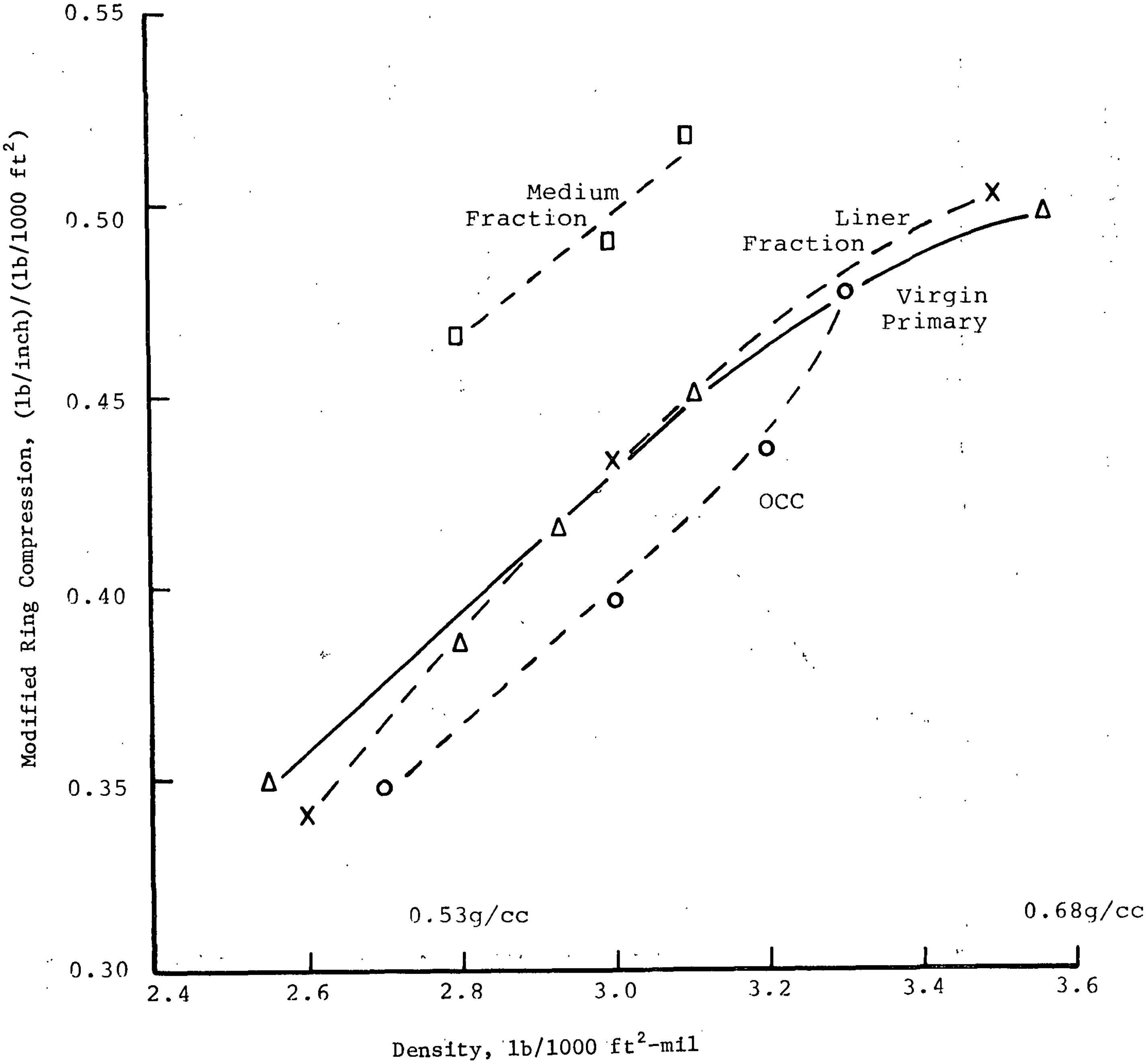

Figure 41. Burst vs. Edgewise Compression Strength for OCC and Virgin Kraft

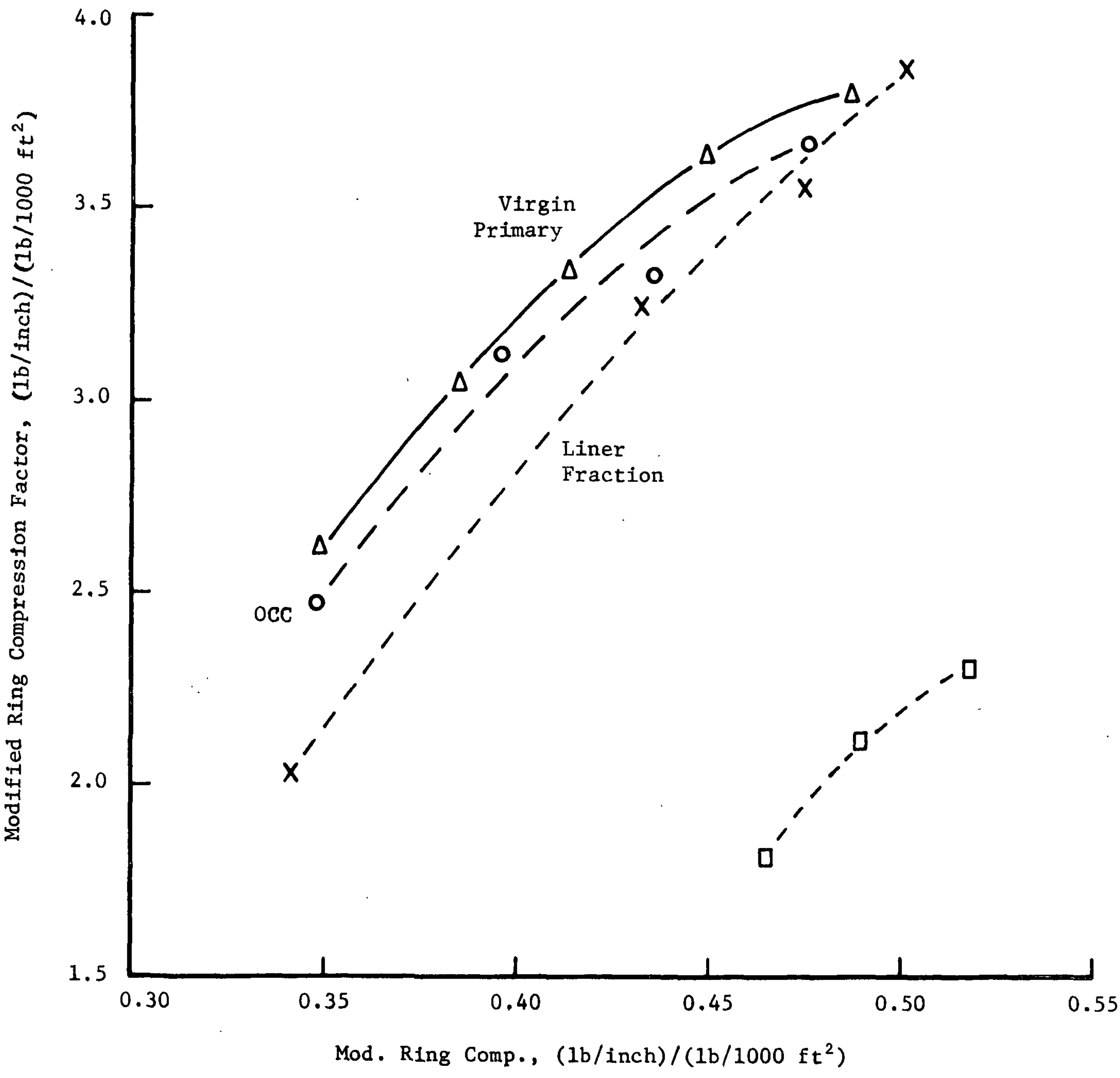

Figure 42. Edgewise Compression Strength vs. Density for OCC and Virgin Kraft

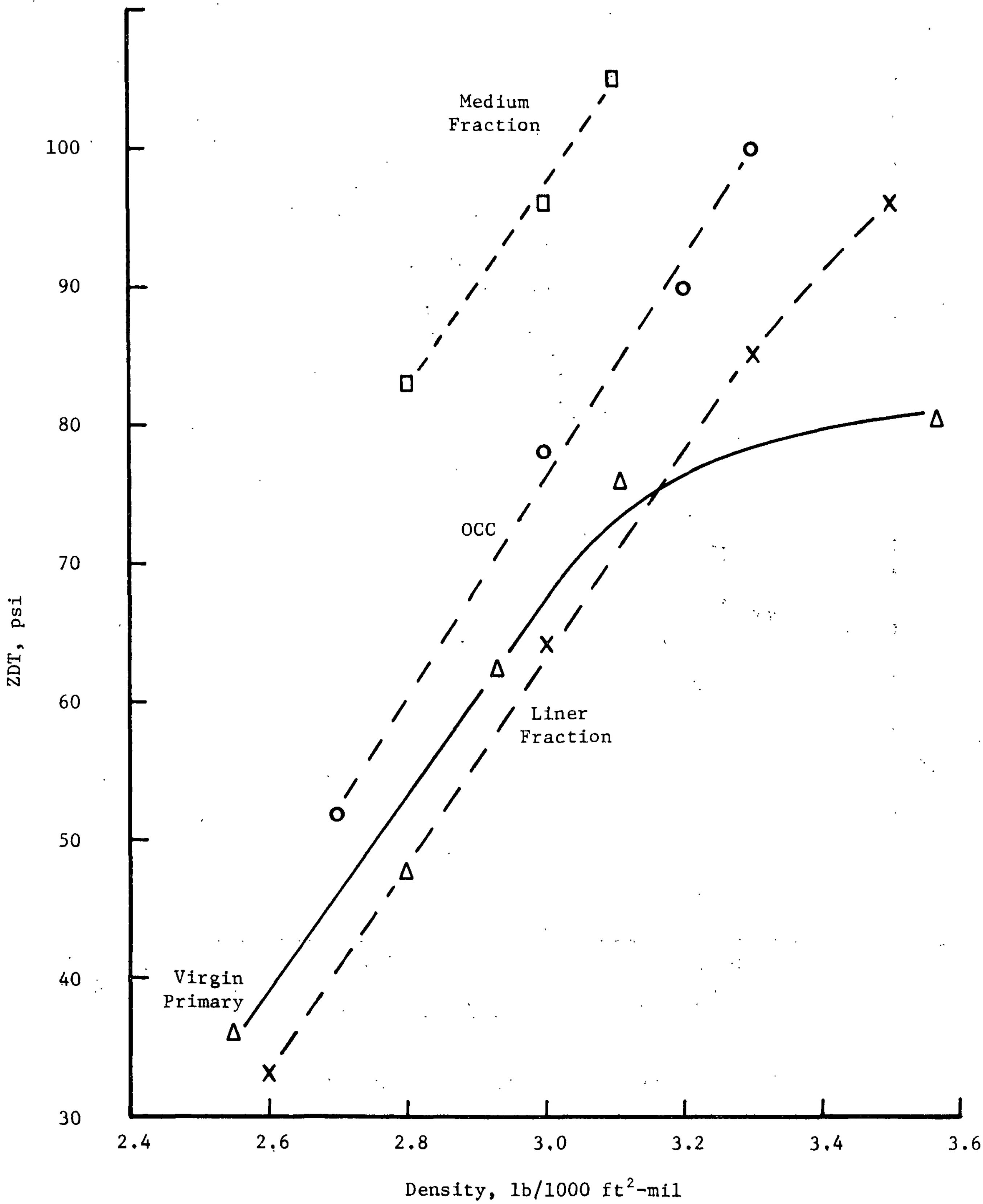

Figure 43. Z-direction Tensile Strength vs. Density for OCC and Virgin Kraft

OCC exhibits intermediate strength roughly in accord with what might be expected for a 70:30 ratio of liner-to-medium.

In general, there appears to be much to be learned as to how the properties of mixtures of virgin kraft, OCC and its fractions depend on the characteristics of the softwood and hardwood components stocks. Fractionation of OCC and separate treatment of either or both fractions may have potential for improving end-use performance of the blended stocks.

ACKNOWLEDGMENTS

The assistance of Mark Van Zummeren and John Peckham in carrying out the research is gratefully acknowledged.

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APPENDIX

TABLE XVIII

BEATER EVALUATION OF VIRGIN KRAFT PRIMARY PULP
(Standard Weight Sheets)

Trial	C.S. Freeness, mL	Basis Weight, lb/1000 ft^2	Caliper, mil	Density, lb/1000 ft^2-mil	Burst Factor	Tensile Factor	Tear Factor	Mod. Ring Factor	Tensile Stiffness	TEA, ft-lb/ft^2	Stretch, %	Concora, psi[a]
					5 Minute Beating Time							
1	765	13.6	6.2	2.20	1.33	0.98	12.39	0.324	137.2	1.5	1.43	--
2	750	13.4	6.3	2.13	1.20	0.83	9.75	0.253	118.8	1.3	1.44	8.2
Av.	758	13.5	6.2	2.16	1.25	0.90	11.07	0.288	128.0	1.4	1.44	
					20 Minute Beating Time							
1	725	14.4	5.6	2.55	2.20	1.34	8.85	0.361	146.5	3.1	2.00	--
2	715	13.6	5.6	2.44	2.13	1.28	8.91	0.324	147.9	2.7	1.87	16.8
Av.	720	14.0	5.6	2.50	2.16	1.31	8.88	0.342	148.2	2.9	1.94	
					35 Minute Beating Time							
1	640	13.8	5.1	2.72	2.69	1.58	7.78	0.362	163.0	4.6	2.48	--
2	640	13.3	5.1	2.62	2.78	1.60	7.67	0.338	163.0	4.3	2.45	26.5
Av.	640	13.6	5.1	2.67	2.74	1.59	7.72	0.350	163.0	4.4	2.46	
					50 Minute Beating Time							
1	435	13.6	4.6	2.93	3.12	1.85	6.41	0.397	178.1	5.8	2.73	--
2	425	13.1	4.7	2.79	3.39	1.83	6.46	0.354	177.1	5.3	2.66	30.9
Av.	430	13.4	4.6	2.86	3.26	1.84	6.44	0.376	177.6	5.6	2.70	
					60 Minute Beating Time							
1	270	14.1	4.5	3.12	3.40	2.03	5.43	0.409	196.7	5.7	2.47	
2	240	12.9	4.5	2.89	3.69	1.92	5.67	0.345	178.1	5.8	2.79	30.3
Av.	255	13.5	4.5	3.00	3.54	1.98	5.55	0.377	187.4	5.8	2.63	

Note: All factors obtained by dividing the test results, usually in English units, by the weight in lb/1000 ft^2.

[a]In 26 lb/1000 ft^2 sheets.